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Phase Report
June 1978

TEST VALIDATION OF EQUIVALENT FULL LOAD IDLE CHANNEL NOISE CONCEPT; RESEARCH REPORT 3-78

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SUNY at Buffalo

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Air Force Systems Command
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During the efforts to analyze the Technical Evaluation Program data, considerable effort was spent to devise an effective method to prove TEP data accuracy and correlation. During this work, a new concept emerged. This approach permits accurate determination of interrelationships among baseband loading, idle channel noise, and noise power ratio. The application of this concept, named Signal to Noise Noise Power Ratio (SNNPR) permits the cross correlation of TEP data gathered at any fortuitous alignment condition, and also allows

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the correction of "poor data" if the bulk of the data is acceptable. The data used as a basis for the new correlation technique was originally gathered empirically but proved to be accurate when tested on measurements from a number of older TEP reports.

DCA authorized a short field test program at Ft. Huachuca, Arizona, supported by the Army to prove the concept. This report covers the approach, the specific measurements on the radios under several degradation conditions, and the end to end test to prove the concept validity and accuracy.

The overall theory of the concept is discussed. A general SNNPR curve is constructed based upon theoretical data only that is universally applicable to all FDM-FM radio links. The accuracy of the approach is examined using a number of TEP link reports.

The SNNPR concept proved operationally usable, and suitable for use in lieu of the present DCA PMP program.

PREFACE

This effort was conducted by R L Feik in association with the State University of New York under the sponsorship of the Rome Air Development Center Post-Doctoral Program for the Defense Communications Agency. Mr. R. I. Hughes of the Defense Communication Engineering Center, DCA was task project engineer and provided overall technical direction and guidance.

The RADC Post-Doctoral Program is a cooperative venture between RADC and some sixty-five universities eligible to participate in the program. Syracuse University (Department of Electrical and Computer Engineering), Purdue University (School of Electrical Engineering), Georgia Institute of Technology (School of Electrical Engineering), and State University of New York at Buffalo (Dept. of Electrical Engineering(act as prime contractor schools with other schools participating via sub-contracts with the prime schools. The U. S. Air Force Academy (Dept. of Electrical Engineering), Air Force Institute of Technology (Dept. of Electrical Engineering), and the Naval Post Graduate School (Dept. of Electrical Engineering) also participate in the program.

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Further information about the RADC Post-Doctoral Program can be obtained from Jacob Scherer, RADC, telephone AV 587-2543, Commertial 315-330-2543.

The author wishes to thank Mr. Hughes, Mr. Bugg, and Mr. Dunn, all of the DCEC, DCA for the continuing support, and the Mr R. H. Levine Assistant Director of the DCEC, for his interest, direction, and guidance. Thanks also go to Mr Weill and Mr Belford of the DCEC for their interest and suggestions during this test.

Special thanks must go to the Digital Transmission Evaluation Project (DTEP) and the Army personnel at Ft. Huachuca, Az. for the excellent support for this test.

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I Introduction

This report describes a special test conducted at Ft. Huachuca, Arizona, September 19th, through October 7, 1977. The objective of the test was to validate a new concept derived during a DCA Technical Evaluation Program (TEP) analysis contract effort. The work was described in Research Report 1-77, dated May 15, 1977, and was titled Technical Evaluation Program Analysis Procedures (TEPAP). NH

The basic concept, as originally expounded in the Technical Evaluation Program Analysis Procedures, stated that it was possible to measure the link idle channel noise (by PMP procedures) at any fortuitous baseband loading. Then using a special set of curves, extrapolate the idle channel noise that the link would provide were the link raised to full baseband loading. That is, the lightly loaded radio idle channel noise measurement is transformed into an 'Equivalent Full Load Idle Channel Noise' reading.

There were several matters addressed during the formulation of the above concept that had been resolved empirically based upon data available in existing TEP reports. It obviously was desirable to refine the concept by direct measurements.

This special test was designed to produce such a curve from straightforward standard test procedures such as those conducted during the DCA TEP. Such a curve has been produced, and the basic concept validated.

A Test Approach

The test duration was limited by several factors: time; money; test hardware and equipment; and personnel availability. It was decided that a three week test period was the best compromise among all factors. The first week was allocated to optimize all radio and mux hardware, to measure initial conditions, and to perform and refine the needed special measurements. The last two weeks were allocated to conduct the test. The test generally followed this schedule.

B Test Support

The Army elements at Ft. Huachuca, assigned to support this test, provided all possible help. All the 'normal' impediments of all field tests were present, such as, test equipment failure, test bed equipment problems, spare parts in limited supply, and one special effect - a lightning hit on the test bed prime power line. The Army response was all that could be desired. The number of people who contributed to the successful completion of the test were numerous, but these few were basic to the accomplishment and should receive specific mention. Mr. Pat Connell, CEEIA, test coordinator for the Army, contributed greatly. The test could not have been completed without his active and full time management and technical support. Mr. Gail Query and Sgt. John Peacock, of the DTEP test bed worked hard to instrument and conduct the test. Specialist Brian Carlon, of the 11th Signal Group, worked long hours to bring the test multiplex into acceptable test condition. Mr. Lane, of the Fort calibration laboratory gave excellent support on the test equipment problems. Mr. Ray Belford, of DCA-DCEC, was the DCA observer, but he worked along with the assigned personnel and contributed to the successful completion of the test. All of these people played a considerable part in the successful test completion.

C Test Bed Description

The actual facility used for this test was a part of the Digital Transmission Evaluation Project (DTEP) at Ft. Huachuca, Az. where the Army is conducting numerous tests, including several for the Defense Communications Agency.

The in-place radio available for this test was the standard DCS radio, FRC-162. This 8 GHz radio is one of the Digital European Backbone configurations. However, when the input and output hardware needed to interface with the twelve megabit stream is bypassed, the remaining elements are identical with the DCS standard

FM radio - and functionally the same as all other FDM-FM configurations in the DCS. The radios used in these tests were in-station looped through attenuators. The input to the modulation amplifier (J-45) is the 'normal' point where a multiplex is connected. The output to the receive mux is the high level IF/demod output J-5. The block diagram for the radio and the TLP's for these two points is given in Figure I-1.

The bulk of the measurements were made on the radios alone with the test equipment connected to J-45 and J-5. The audio-to-audio tests were conducted in a slightly modified conventional configuration. The final concept proof test configuration is portrayed in Figure I-2.

The ideal test complex would not have needed the white noise test set. However, the multiplex available at the test bed was only 60 channels and the radio was 600 channels. Thus, the white noise test set was used to simulate the audio channel loading that normally would have been placed through the multiplex. This unusual structuring of the hardware was technically acceptable and also permitted measuring the loop NPR while the audio test was in progress. Thus, the actual condition of the test compliment was fully known.

Block Diagram of AN/FRC-162
as configured for this test

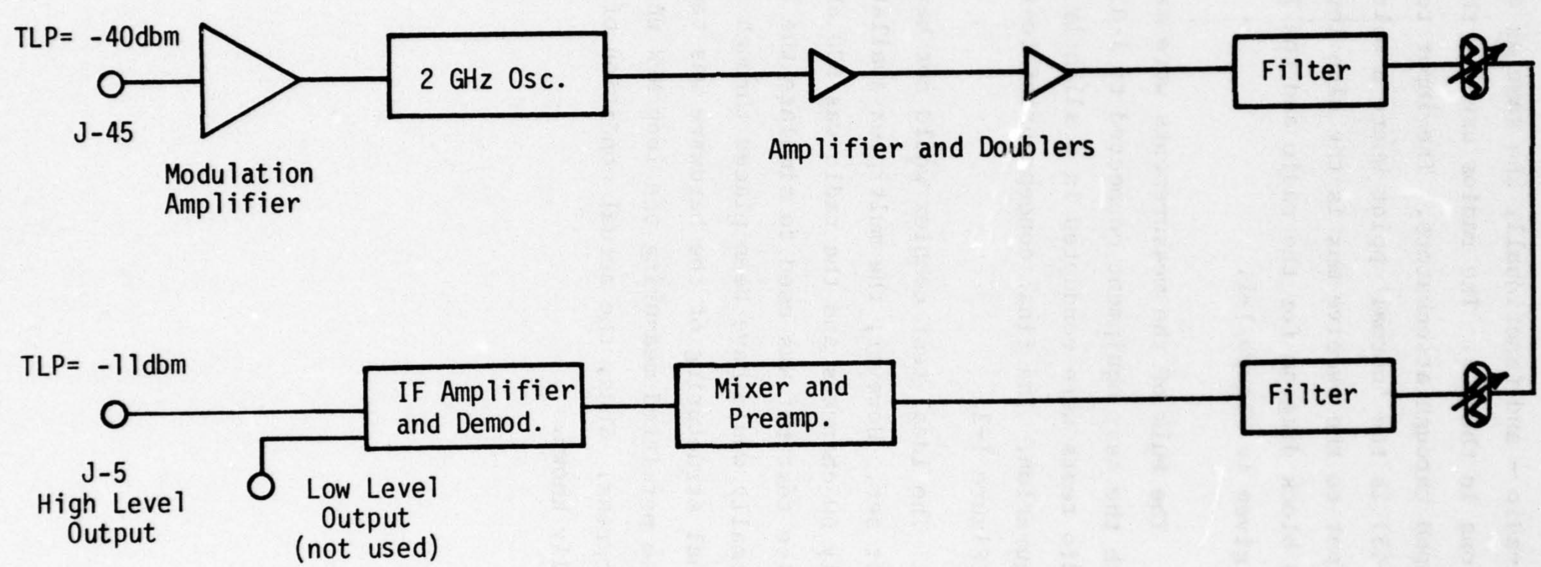


Fig. I-1

Concept Prooftest Hardware Configuration

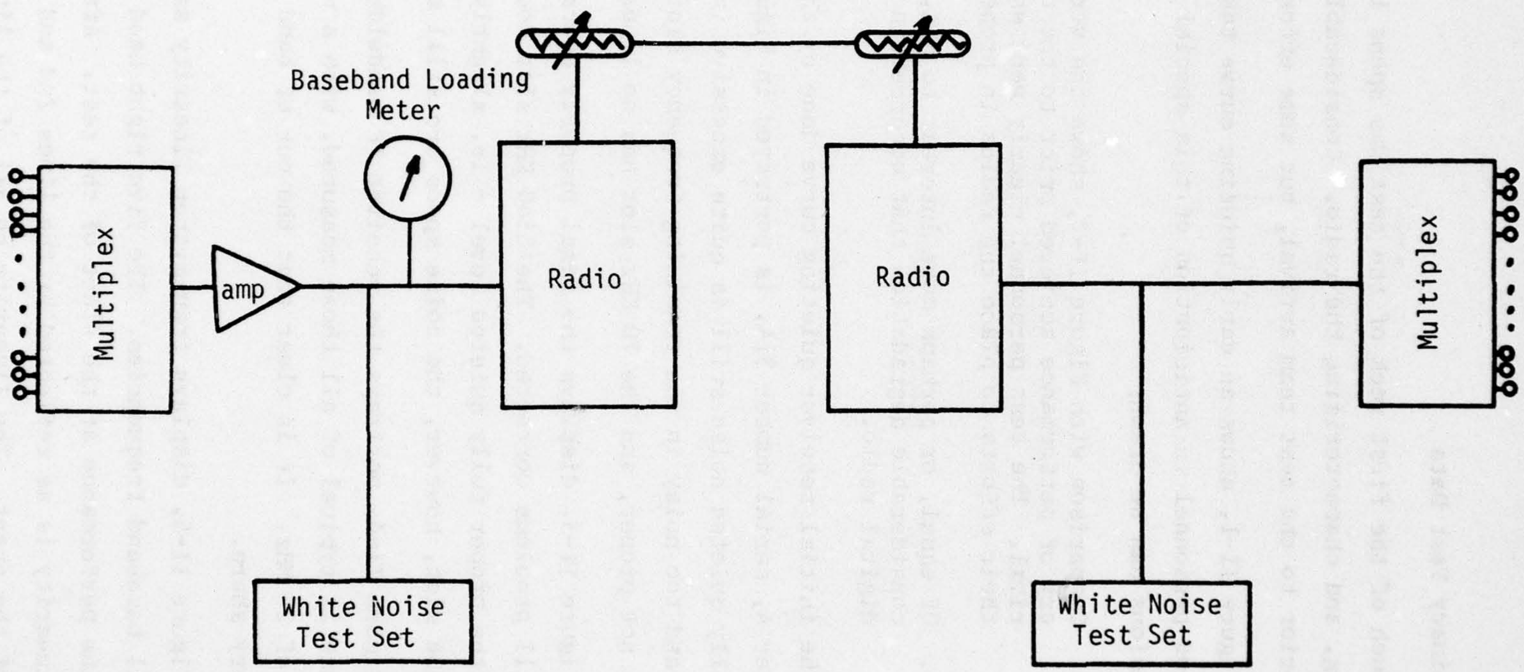


Fig. I-2

II Preliminary Test Data

Much of the first week of the test was spent in realigning, peaking, and characterizing the radio. Considerable work had been done prior to the test team arrival, but some effort still remained.

Figure II-1, shows an early quieting curve taken by the Army test bed personnel in anticipation of this special test. Several conclusions can be drawn:

a. Comparison with Figure II-2, shows the very large recovery of performance achieved prior to the test team arrival. The test personnel clearly were energetic in their efforts to place the radios in proper alignment.

b. Of equal, or perhaps more interest to DCA, is the very considerable degradation that occurred in a solid state digital radio.

The initial receiver quieting curve done by the test team on receiver A, serial number 31A, is portrayed in Figure II-2. Clearly, the fully quieted noise still is quite excessive in the 70 and 534 slots and too noisy in the remaining frequency slots. The FM threshold is not proper, and the 70 KHz slot has no linear portion.

Figure II-3, displays the final properly operating receiver with all problems corrected. The 5340 KHz slot does not quite reach the proper fully quieted level - ie. slightly quieter than the 2438 slot, however, the noise specs are still met.

Figure II-4, portrays the receiver IF bandwidth. The rippled response is typical of all those measured, with a nominal bandwidth of 25 MHz. It is clear that the out of band rejection is not very sharp.

Figure II-5, displays transmitter linearity as measured at several baseband frequencies. The five right hand curves represent the performance at the start of the test. After alignment, the linearity is as reflected by the lines 2nd and 3rd from the left of the chart. The linearity on all of the lines, except one, was measured at 2 GC in accordance with the tech order. The line at the extreme left is the linearity after final alignment, and was measured at 8 GHz using a special non-standard test procedure. Good linearity is obviously achieved.

Two NPR curves were run after completion of the preliminary alignment, but before full "like new" performance was achieved. Figures II-6 and 7, show these curves. One was run at 600 and the other at 1200 channel loading. The radio is nominally a 600 channel radio, although the IF bandwidth could support more than 1200.

After full premium alignment, the NPR curve was as displayed in Figure II-8. The radio could almost meet performance criteria for either 600 or 1200 channels.

Figure II-9, shows the discriminator curves for two receivers. These curves are typical of most radios maintained by competent technicians - good but not proper. The full and proper alignment, using broad 'Scope Creek' type experience, rather than the specific tech order instructions, resulted in more than a 5 db gain in peak NPR values. This proper alignment also moved the peak NPR value from a baseband loading of about +10 dbmØ to just above the full DCA loading of +17.8 dbmØ. This alignment entailed adjustment of both the discriminator transformer primary and secondary in addition to the "tilt" and "bow" controls described in the tech order. Tilt and bow are the only ones available through IF stage covers.

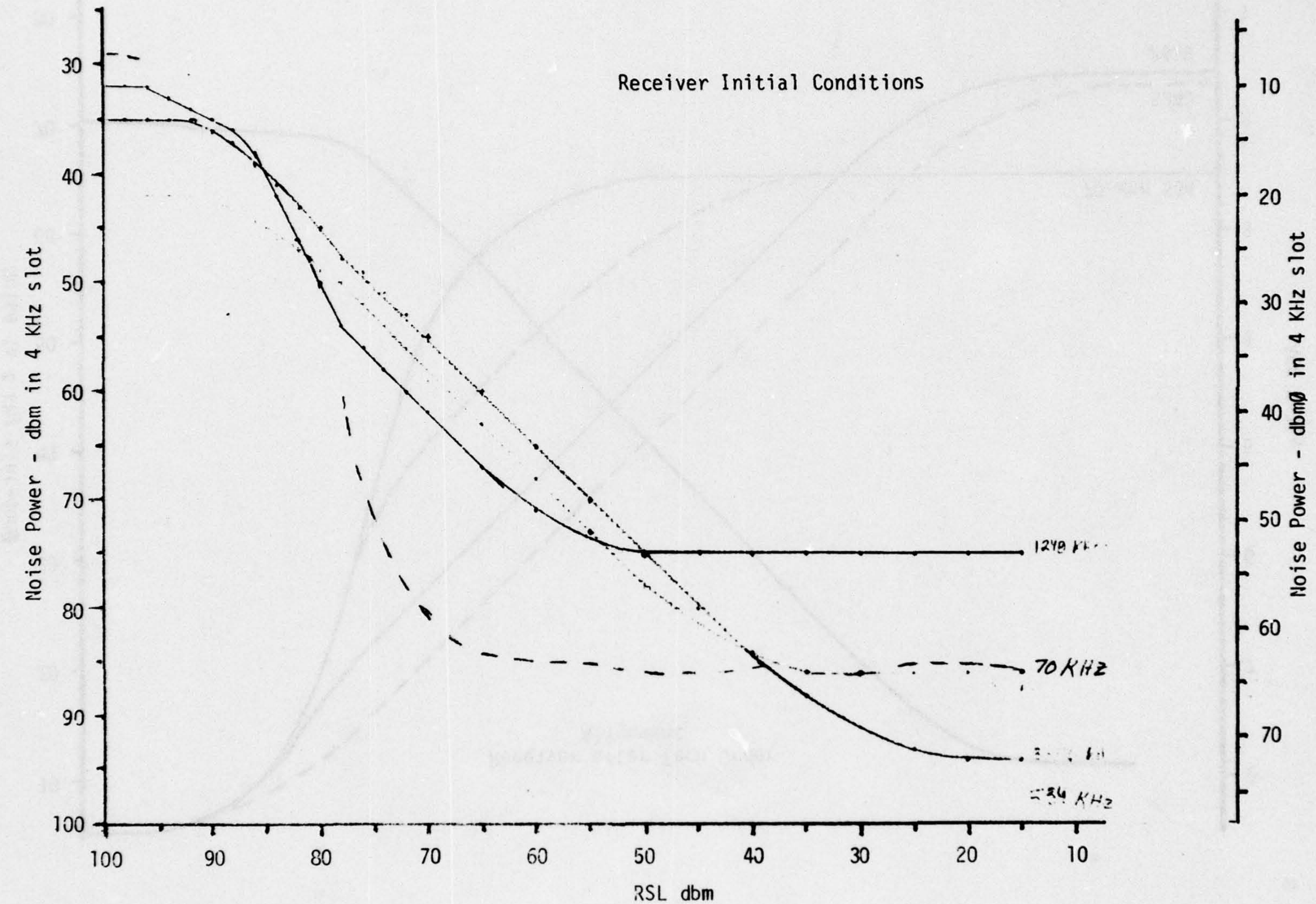

Receiver Initial Conditions
Noise Power - dbm in 4 KHz slot
Noise Power - dbmØ in 4 KHz slot
RSL dbm
30
40
50
60
70
80
90
100
10
20
30
40
50
60
70
100
90
80
70
60
50
40
30
20
10
70 KHz

Fig. II-1

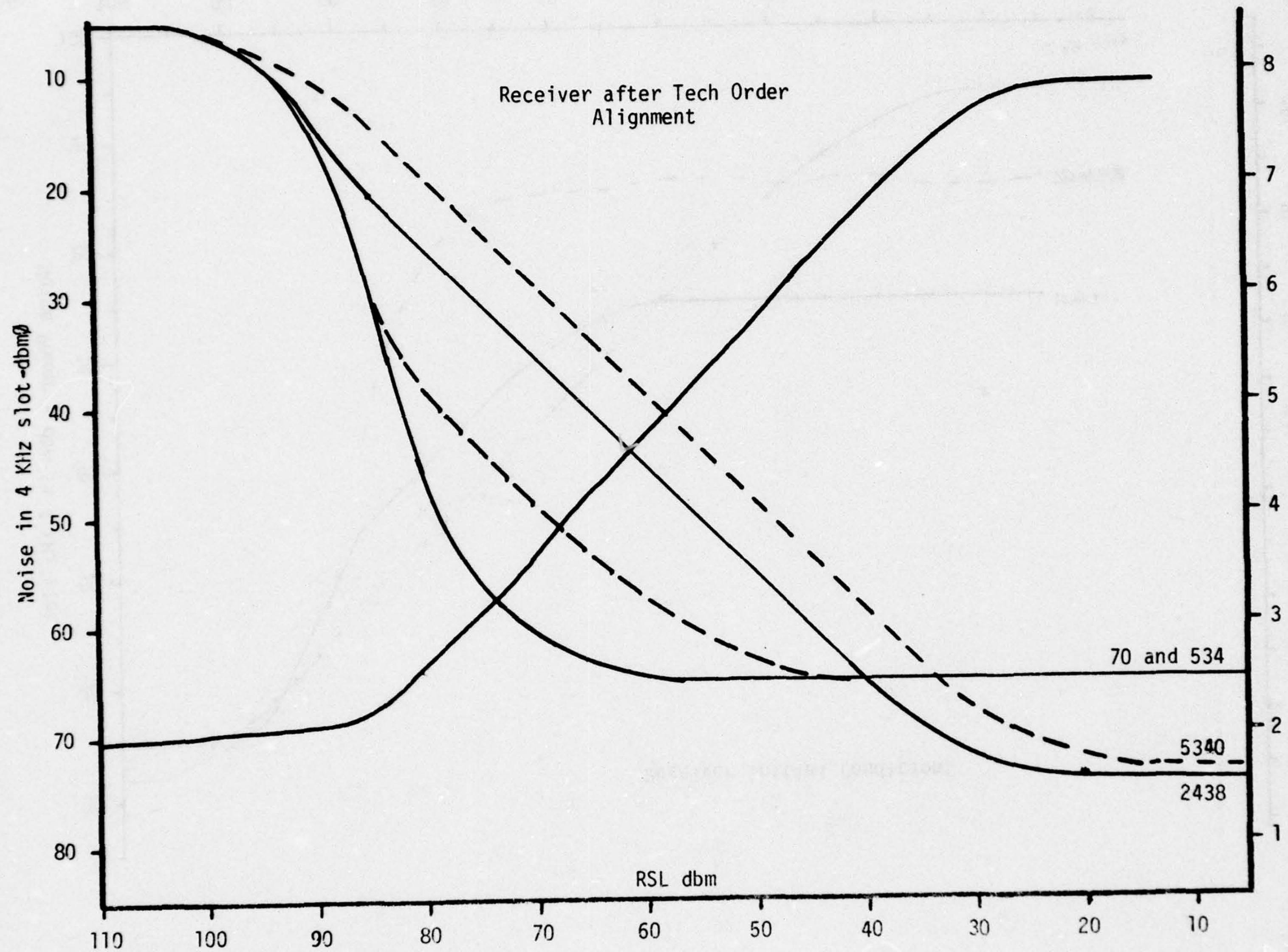
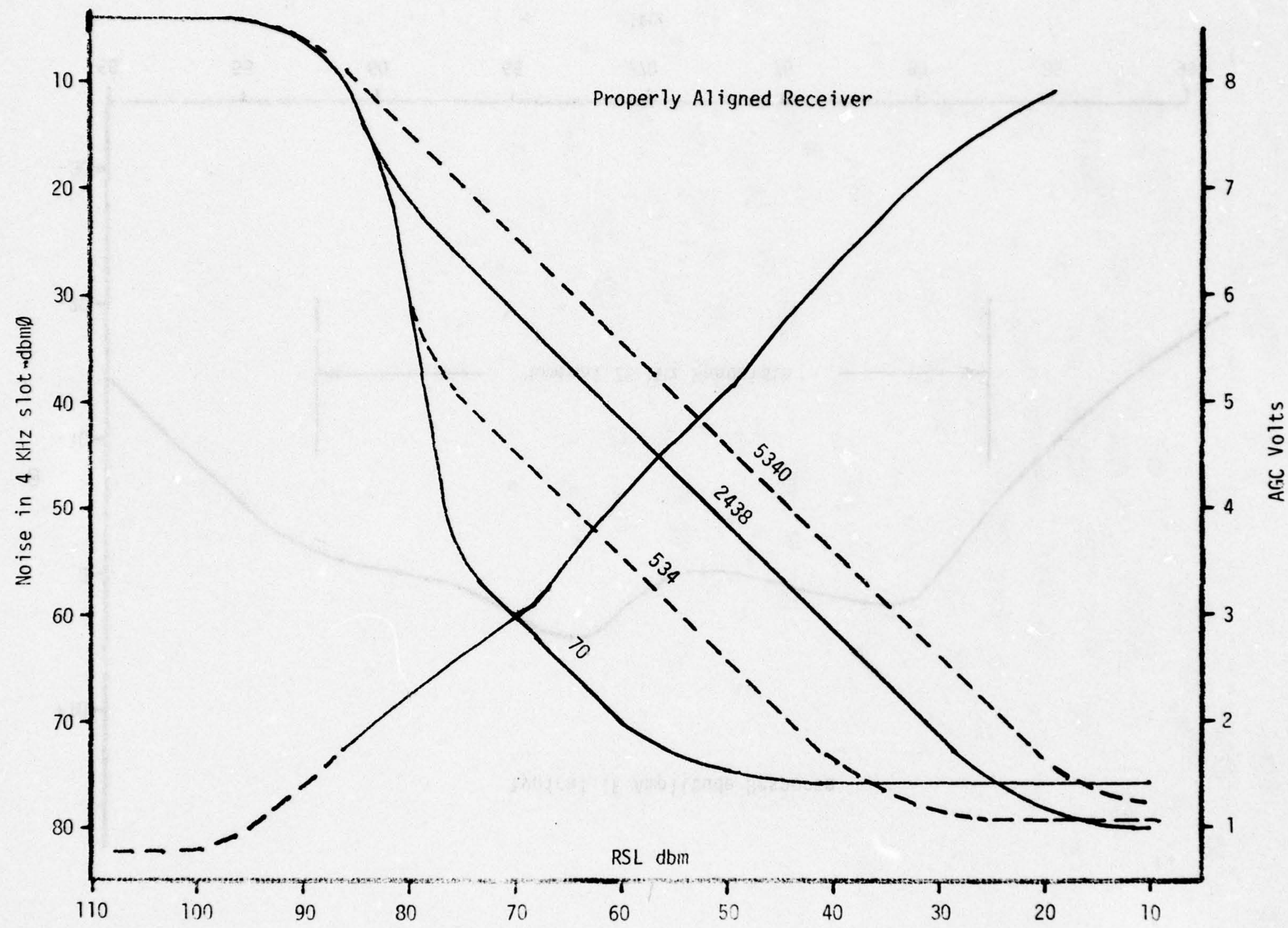

Receiver after Tech Order Alignment
Noise in 4 KHz slot-dbmØ
10
20
30
40
50
60
70
80
AGC Volts
8
7
6
5
4
3
2
1
70 and 534
5340
2438
RSL dbm
110
100
90
80
70
60
50
40
30
20
10

Fig. II-2



Properly Aligned Receiver
5340
2438
534
70
Noise in 4 KHz slot-dbmØ
AGC Volts
RSL dbm
10
20
30
40
50
60
70
80
110
100
90
80
70
60
50
40
30
20
10
8
7
6
5
4
3
2
1

Fig. II-3

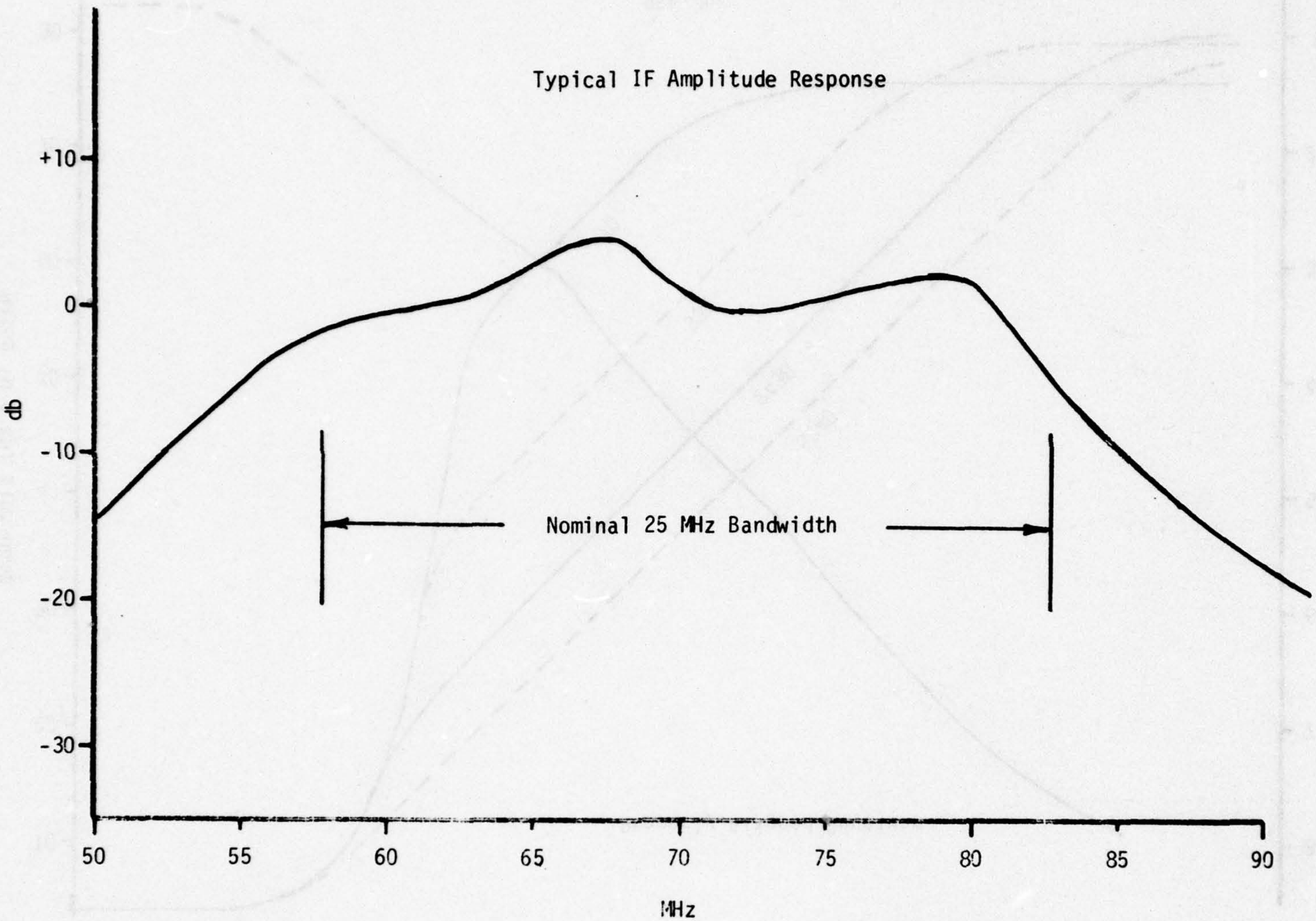

Typical IF Amplitude Response
Nominal 25 MHz Bandwidth
db
+10
0
-10
-20
-30
50
55
60
65
70
75
80
85
90
MHz

Fig. II-4

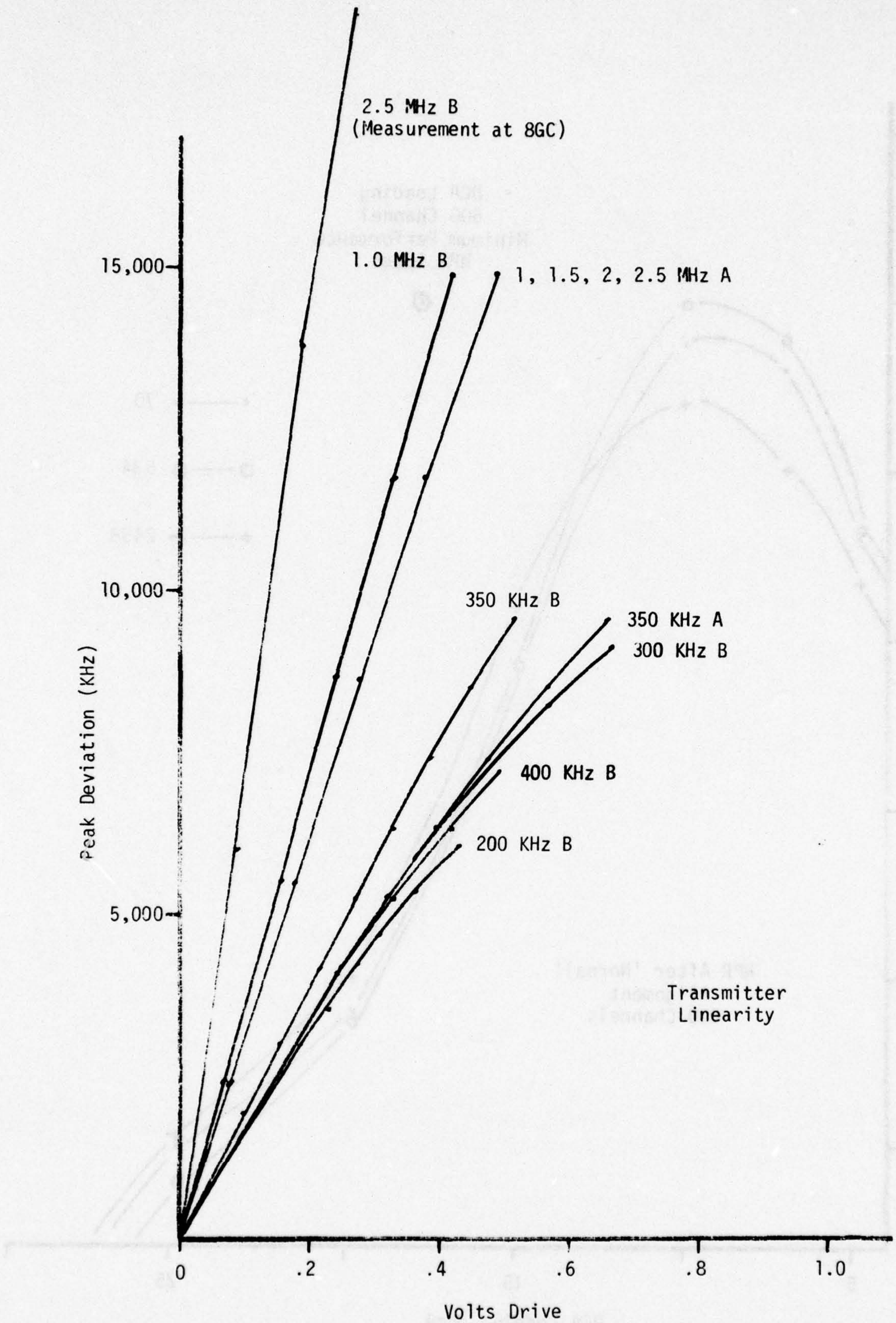

2.5 MHz B
(Measurement at 8GC)
1.0 MHz B
1, 1.5, 2, 2.5 MHz A
15,000
10,000
5,000
350 KHz B
350 KHz A
300 KHz B
400 KHz B
200 KHz B
Peak Deviation (KHz)
Transmitter
Linearity
0
.2
.4
.6
.8
1.0
Volts Drive

Fig. II-5

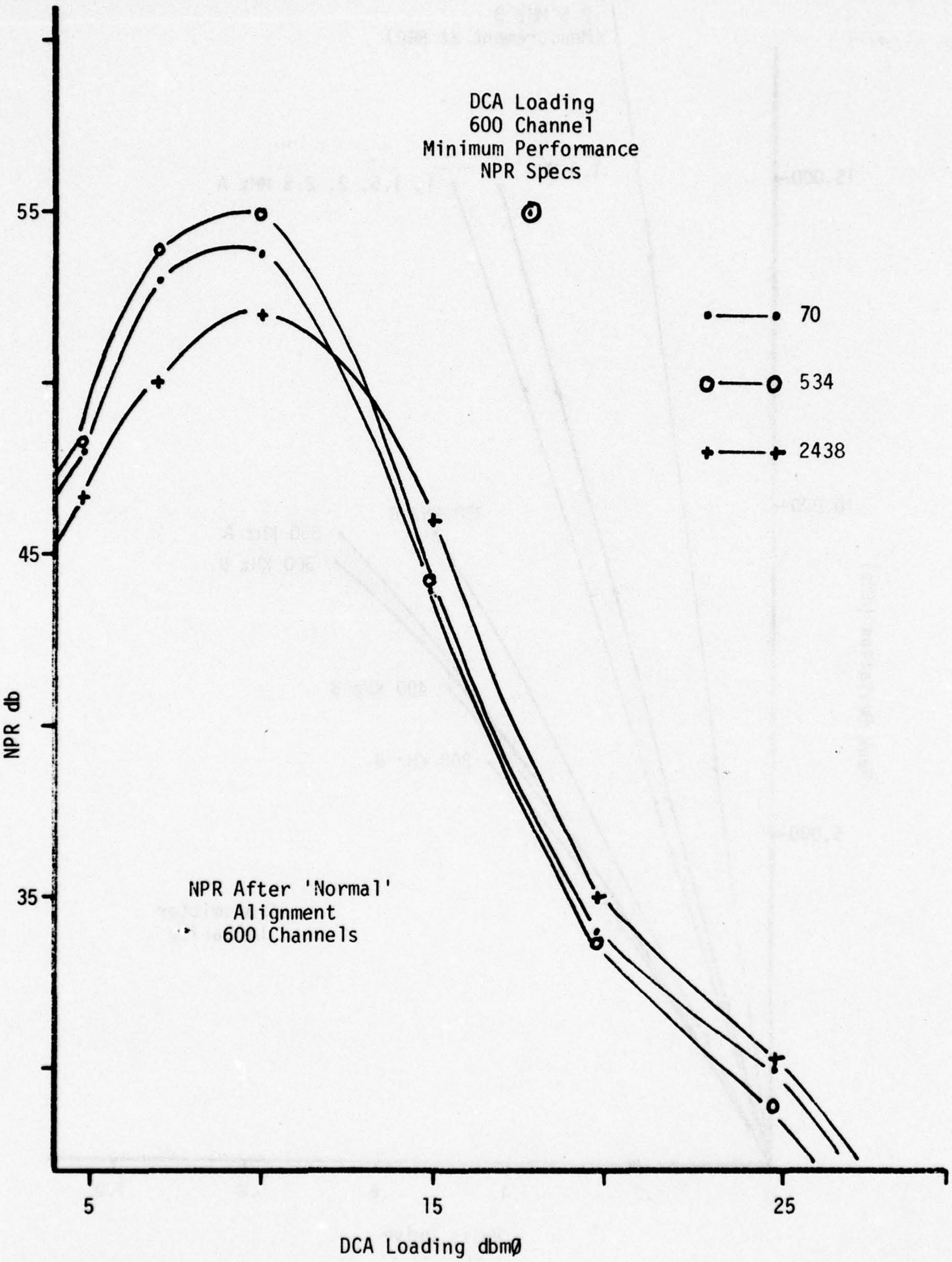
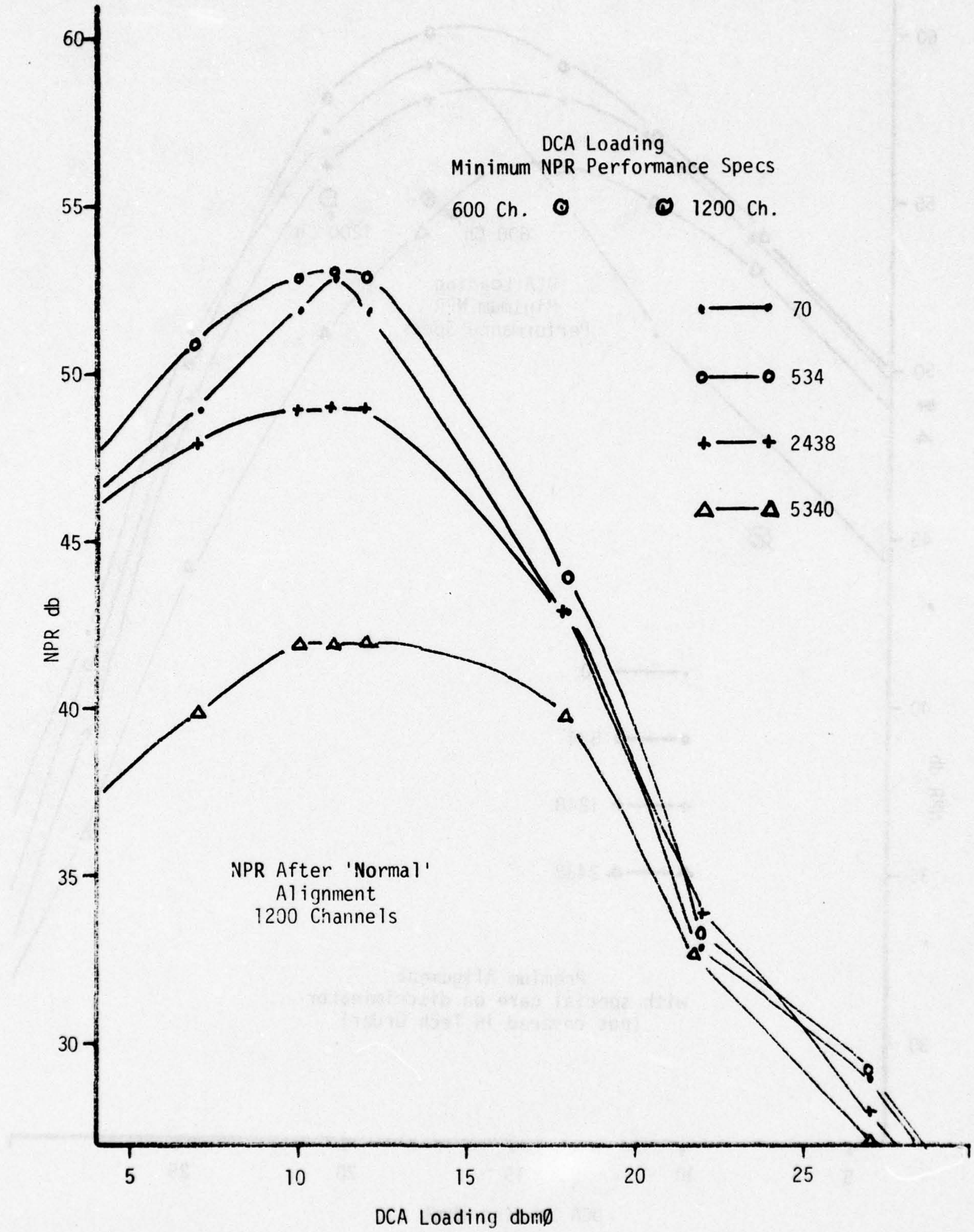

DCA Loading
600 Channel
Minimum Performance
NPR Specs
70
534
2438
55
45
35
NPR db
NPR After 'Normal'
Alignment
600 Channels
5
15
25
DCA Loading dbmØ

Fig. II-6


DCA Loading
Minimum NPR Performance Specs
600 Ch.
1200 Ch.
70
534
2438
5340
NPR After 'Normal'
Alignment
1200 Channels
NPR db
60
55
50
45
40
35
30
5
10
15
20
25
DCA Loading dbmØ
Fig. II-7

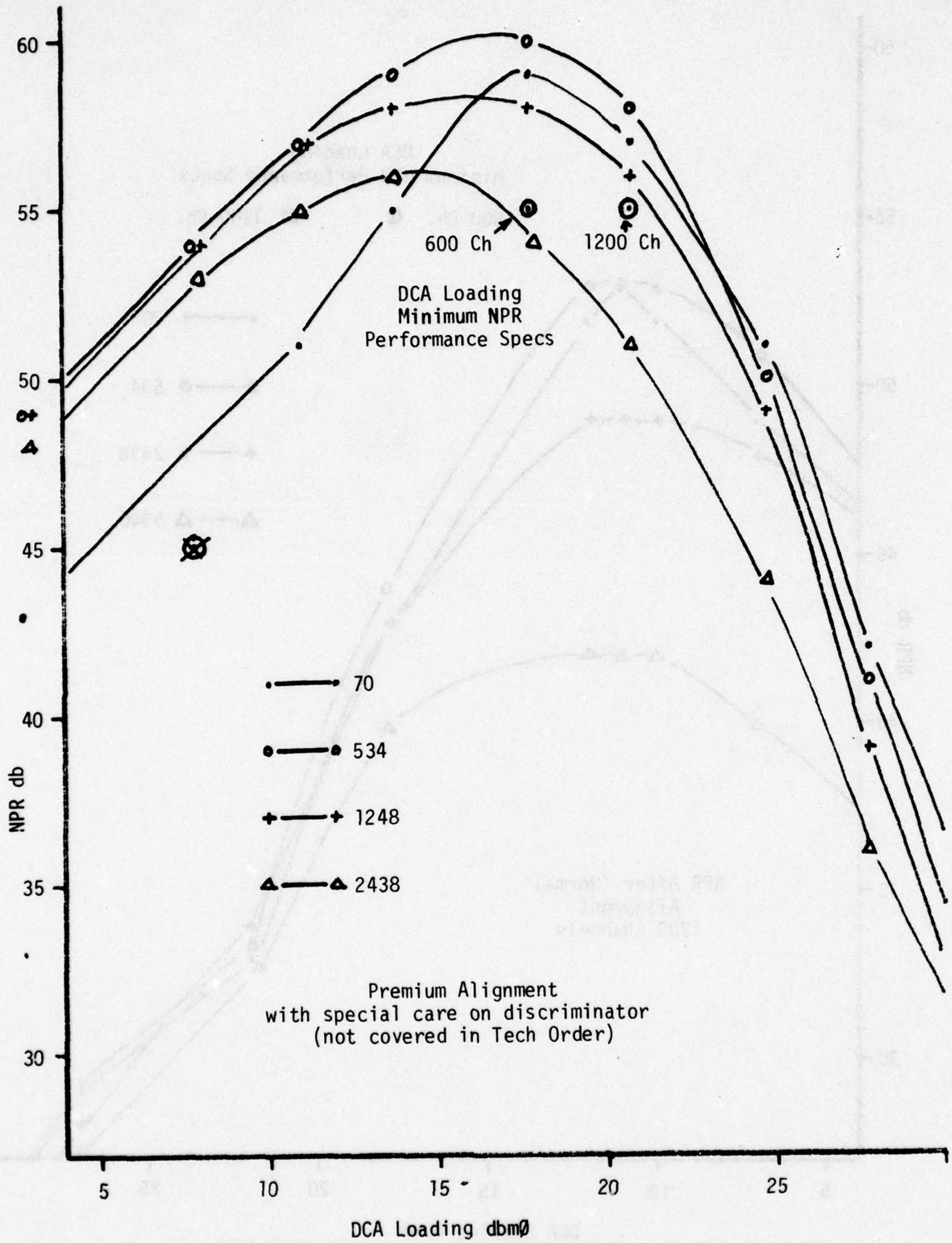

60
55
50
45
40
35
30
NPR db
600 Ch
1200 Ch
DCA Loading
Minimum NPR
Performance Specs
70
534
1248
2438
Premium Alignment
with special care on discriminator
(not covered in Tech Order)
5
10
15
20
25
DCA Loading dbmØ

Fig. II-8

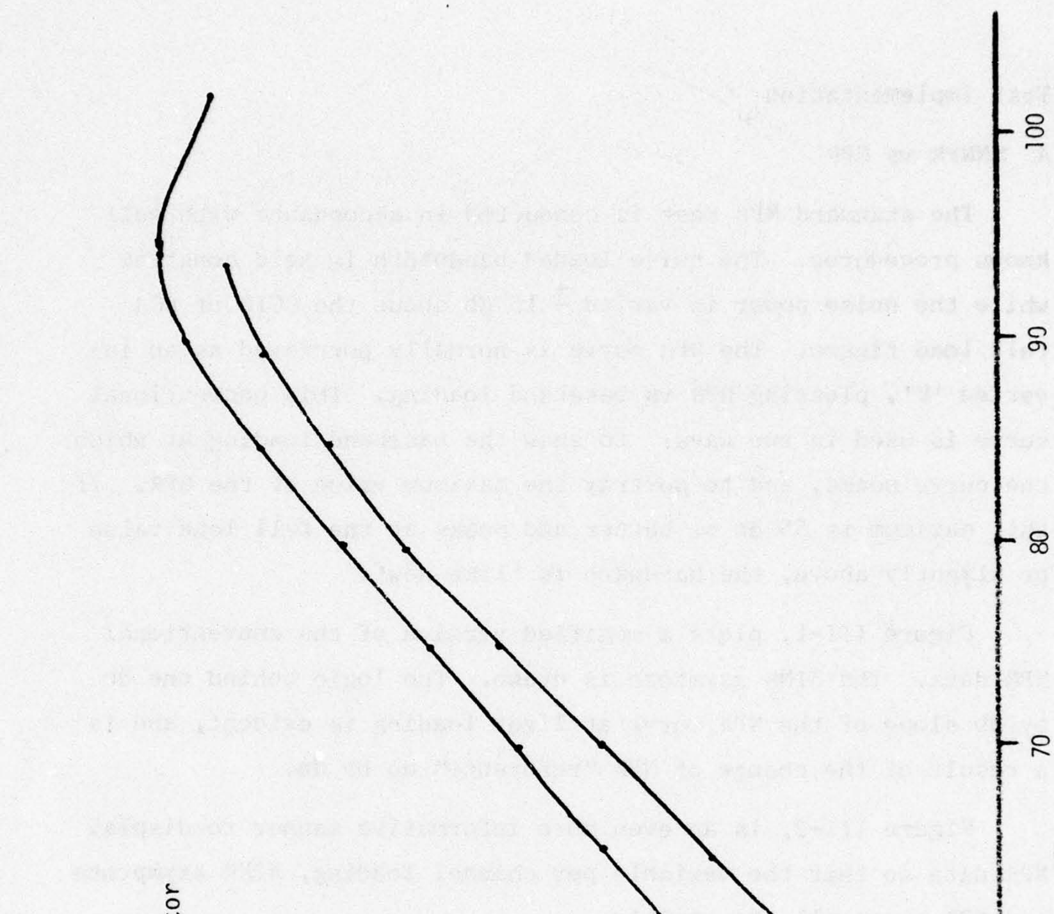

Receiver Discriminator
Curves
Volts
2
3
4
5
6
7
8
MHz
40
50
60
70
80
90
100

Fig. II-9

III Test Implementation

A SNNPR vs NPR

The standard NPR test is conducted in accordance with well known procedures. The noise loaded bandwidth is held constant while the noise power is varied $\pm$ 15 db about the CCIR or DCA full load figure. The NPR curve is normally portrayed as an inverted 'U', plotting NPR vs baseband loading. This conventional curve is used in two ways: to show the baseband loading at which the curve peaks, and to portray the maximum value of the NPR. If this maximum is 55 db or better and peaks at the full load value or slightly above, the hardware is 'like new'.

Figure III-1, plots a modified version of the conventional NPR data. The BINR asymtote is drawn. The logic behind the db by db slope of the NPR curve at light loading is evident, and is a result of the change of NPR "reference" db by db.

Figure III-2, is an even more informative manner to display NPR data so that the variable per channel loading, BINR asymptote and NPR curve all are visible.

Figure III-3, is a further presentation, derived from Figure III-2. This curve is constructed starting from the full load NPR parameters of per channel loading, and BINR. The actual BINR is hardware related, is constant and represents the noise floor of the hardware. Therefore, it is possible to plot the BINR at 64 db in this example. The NPR related curve (defined as signal to Noise Noise Power Ratio -SNNPR) can be plotted in db above BINR. The fact that in the NPR case the variable loading comes from varying the per channel loading and in the SNNPR the changed loading results from constant per channel but variable bandwidth, makes no difference to the radio.

This SNNPR constant per channel loading curve can be derived as shown above simply from the standard NPR curve. This curve may also be measured directly using the standard white noise test set as described just below in this report.

The standard white noise test set comes with a selection of filters. Those used for these tests, and the standard noise measurement slots are shown in Figure III-4. The baseband loading could only be varied from +7.3 to +24.0 dbm$\emptyset$, while holding the per channel loading constant. In some filter configurations such as the +7.3 loading only the 534 slot can be used to assess the intermodulation. This unavoidable fact explains why at light loading all baseband slots cannot be measured and plotted. The baseband loading above +21 dbm$\emptyset$ are only generally indicative and are not at all precise, because of instrumentation and hardware bandwidth problems.

The test procedure used to measure the data for the new curve is generally the same as for a conventional NPR, with only the *noise bandwidth and constant* per channel loading matters changed. The new procedure requires only slightly more time to conduct.

During the test period at Ft. Huachuca, two independent in-station looped links were available. T_A to R_A was used as the variable and T_B to R_B was held in 'like new' condition as a control. Several times during the test sequence and at the termination of the tests, T_A to R_A was returned to 'like new' condition to assure that the degradations being characterized were in fact those introduced intentionally, and that no faults or accidental troubles appeared.

Figure II-8, is the conventional NPR presentation for the test radio. Figure III-5, is the measured constant per channel-variable bandwidth equivalent curve plot. This latter curve is called the signal-to-noise NPR portrayal. For the balance of the report, NPR means the conventionally derived data. SNNPR means intermodulation data gathered in the special constant per channel loading level manner. This latter curve is the one that was taken on the T_A-R_A and represents the "like new" SNNPR. This is the standard against which the degraded SNNPR's must be compared.

It is important to note that NPR and SNNPR are identical at one point. At the standard DCA full load, the per channel loading and loaded bandwidth is the same in both tests; at that point and only that point. Thus, the NPR can be directly read at the full +17.8 dbmØ point on the SNNPR curve.

It is informative to examine each SNNPR curve in isolation to observe characteristics associated with the various degradations. It is more useful, in connection with this special test concept, to view on one chart the several SNNPR curves resulting from the highly varied and divergent degradations introduced. Such a composite figure was prepared and is presented at the termination of the series of graphs portraying each individual degradation.

B SNNPR vs Degradation

In order to portray the changes that occur in the SNNPR curves as the link degrades, a series of SNNPR curves were run at various degradations.

Two classes of problems can be present in a link. Amplitude distortions can appear in the transmitter modulator, receiver discriminator, or amplifiers sections. Phase distortions can show in tuned circuits in the RF and IF, in wave guide and antenna elements, and in the propagation path. In this test, the phase distortions were entered in the IF bandwidth determining filters. The IF shaping filter was mal-tuned to create ripple in the bandpass. One test was run with a 6.7 MHz IF filter vs the normal 25 MHz.

The amplitude non-linearities were actually injected into the discriminator by 'bow' and 'tilt' adjustments because of ease of entry and repeatability. After the radio had been placed in "like new" condition, the bow and tilt controls were used to introduce known degradations, and later the radio returned to the original like new performance levels. Figures III-6,7, and 8, display three increasing degradations injected only by "bow." Figures III-9 and 10, portray the SNNPR deteriorations due only to tilt mal-adjustment. Figure III-11, shows the extreme variation in a combination of bow and tilt.

Since in real life it is unlikely that one single deterioration only would be present, a curve was derived with a combination of bow and tilt. The NPR selected was 42 db at full DCA loading. Figure III-12, shows the SNNPR curve for this composite, 'typical' degradation.

This composite 42 db NPR degradation was the deterioration present in the radio when the audio-to-audio tests were run to prove the operational suitability of the basic 'Equivalent full load idle channel noise' concept.

Figure III-13, is an example of phase distortion. In this case, the distortion was caused by introducing excessive ripples into the receiver IF filter. The IF phase response is shown on the insert.

The NPR values at full baseband loading vary from 51 db in the 70 KHz slot to 39 db in the 2438 slot. The average value would be 42.6 db using picowatt averaging. It is of little operational import that the noise in the frequency slots is different, the ICN of the channels, averaged across the baseband would approximate the value achieved if all the slots were -42.6 db as produced by amplitude degradation.

The important observation is that the phase distortion curves have the appropriate shape. For example, in Figure III-13, the 70 KHz slot has an NPR of 51 db, and it is shaped the same as the amplitude non-linearity curve derived by discriminator mal-adjustment to a 51 NPR. Similarly for the other slots.

Figure III-14, is the SNNPR curve taken with the 6.7 MHz wide IF. The average NPR is 37.5 db. Clearly, the effect of phase and bandwidth difficulties are quite different from those of amplitude non-linearities. Equally obvious, is the easy identification of phase problems, evidenced by the spread of the various frequency slots. The channel noise averaged across the baseband would approximate that of a -37.5 db NPR radio, and would evidence a high disparity between low and high baseband frequency channels.

In general, the amplitude distortion curves parallel each other and behave predictably. There is one point of note, although not of major importance. All bow introduced degradations are parallel and have a general concave downward shape. The extreme tilt related problems produce SNNPR curves slightly concave up at light baseband loadings.

Figure III-15, portrays all of the amplitude distortion curves on a single graph. The phase distortion SNNPR curves are not plotted on the graph to reduce the confusion. All of the curves represent the 534 KHz mid slot SNNPR curves, and approximate the curves that would be used in operational use.

All curves were run on the T_A -R_A pair except the 61 NPR value. This curve was the result of premium alignment of all adjustments. All combinations of A&B transmitters and A&B receivers exceeded 59 db NPR, proving true quality alignment and ruling out compensating adjustments. Obviously, holding 55 db NPR in operational use should be easy.

There is one matter unresolved at higher baseband loading levels - above +21 dbm∅. Test equipment constraints precluded proper noise bandwidth limitations. Thus, at "full" load unrestricted by filters, the Marconi white noise test set has a 2 db bandwidth of 18 MHz. Thus, the transmitter load is a very wide noise spectrum. When this happens, the radio alarms trigger. The per channel loading then was reduced several db.

When this wide band signal, reduced somewhat in bandwidth in the transmitter, progresses through the receiver, it emerges with a 3 db bandwidth of 10.9 MHz - a loading of +24 dbmØ. Time, instrumentation, and test objectives did not permit in depth analysis of this peculiar loading. This information is given to explain why the SNNPR curves above the +21 dbmØ loading are only generally indicative of the proper behavior, and are not usable as precise measurements.

This SNNPR concept was designed to detect links where the apparently 'green' ICN readings were due to light loading and not to proper alignment. In operational use, baseband loadings more than 3 db above full load will always result in noisy channel performance, and the baseband loading by itself is clearly indicative of the problem. Thus, measurement questions above +21 dbmØ are not considered significant to validation of this concept.

C Construction of Baseband Loading vs ICN vs NPR Curve

1 Multiplex Curve

Now that the radio SNNPR curves for a variety of degradations are available, the next step in the construction of the desired baseband loading vs ICN vs NPR curve can be accomplished. Theoretically, a baseband loading vs channel noise for the test multiplex should have been run, but time and hardware availability did not permit. However, this imposes little hardship, since TEP teams had prepared such curves on several types of equipment. The resultant curves were within measurement accuracy, identical. Figure III-16, shows the IM and BINR contributions and the composite mux noise response. The BINR routinely runs -66 to -70 dbmØ, 3 KHz weighted. (In some DCS stations, the 3 KHz ICN readings are more degraded to -60 to -62 dbmØ, because of low frequency hum at 60, 120, 180, or 400 Hz. At these sites C msg readings are used arithmetically corrected to 3 KHz). The Intermodulation in the mux is consistent among the multiplexers and is as portrayed. The concave up shape at high baseband loadings reflects the response to built-in limiters.

Thus, the standard mux curve is used for this special test.

2 Radio Curve

A special audio-to-audio test was run to prove that the SNNPR theory and practice agree in the field. The special test was set up using degradations introduced by both bow and tilt. Since the actual SNNPR could be measured easily during the audio measurements, specific curve data was gathered during the audio end-to-end test. Figure III-17, shows the resultant curve.

Note that the general shape of the curve is the same as all the other's SNNPR. Thus, it is obvious that the special test configuration had little affect on the curves. The actual measured NPR status of the radio was 44 db during the proof test - a degradation quite often encountered in field DCS links.

3 Composite Curve Construction

The generation of the composite baseband loading vs ICN vs NPR curve is simple, and entails only the appropriate db graphical addition of the multiplex and the radio curves. At the 55 db NPR (55 db SNNPR) point no special concerns are involved. The construction of lower value SNNPR curves will be discussed later.

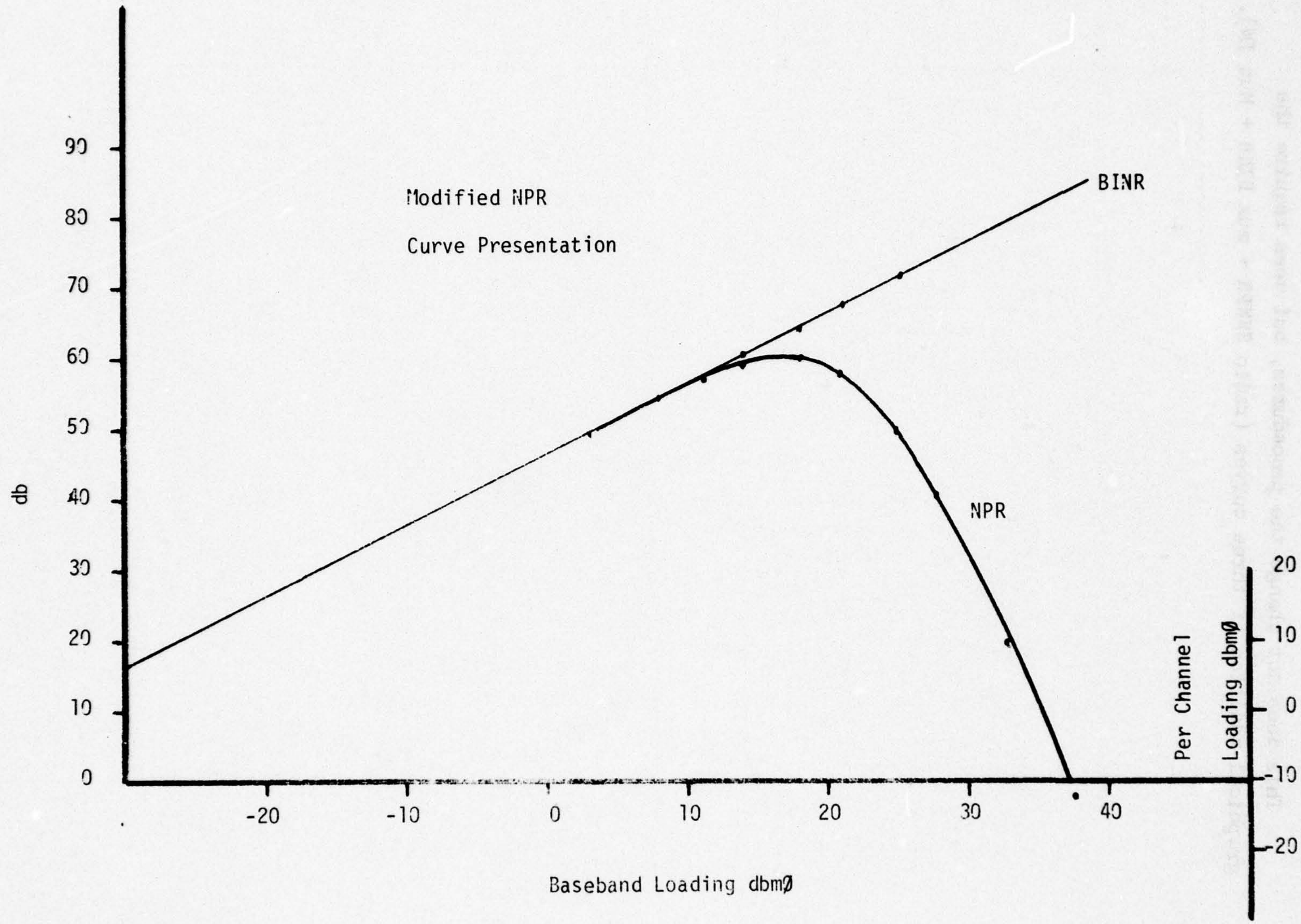
Had the test configuration been 'proper', that is, had the radio been 'like new', and the multiplex quiet, the 55 db SNNPR curve would have been constructed as follows:

a. Plot graph scales and recall in this example ICN=NPR+10 db
b. Plot the mux composite curve with BINR=-65 dbmØ
c. Plot the average radio SNNPR curve = 55 db NPR
d. Add the two curves graphically using picowatt addition.

See Figure III-18.

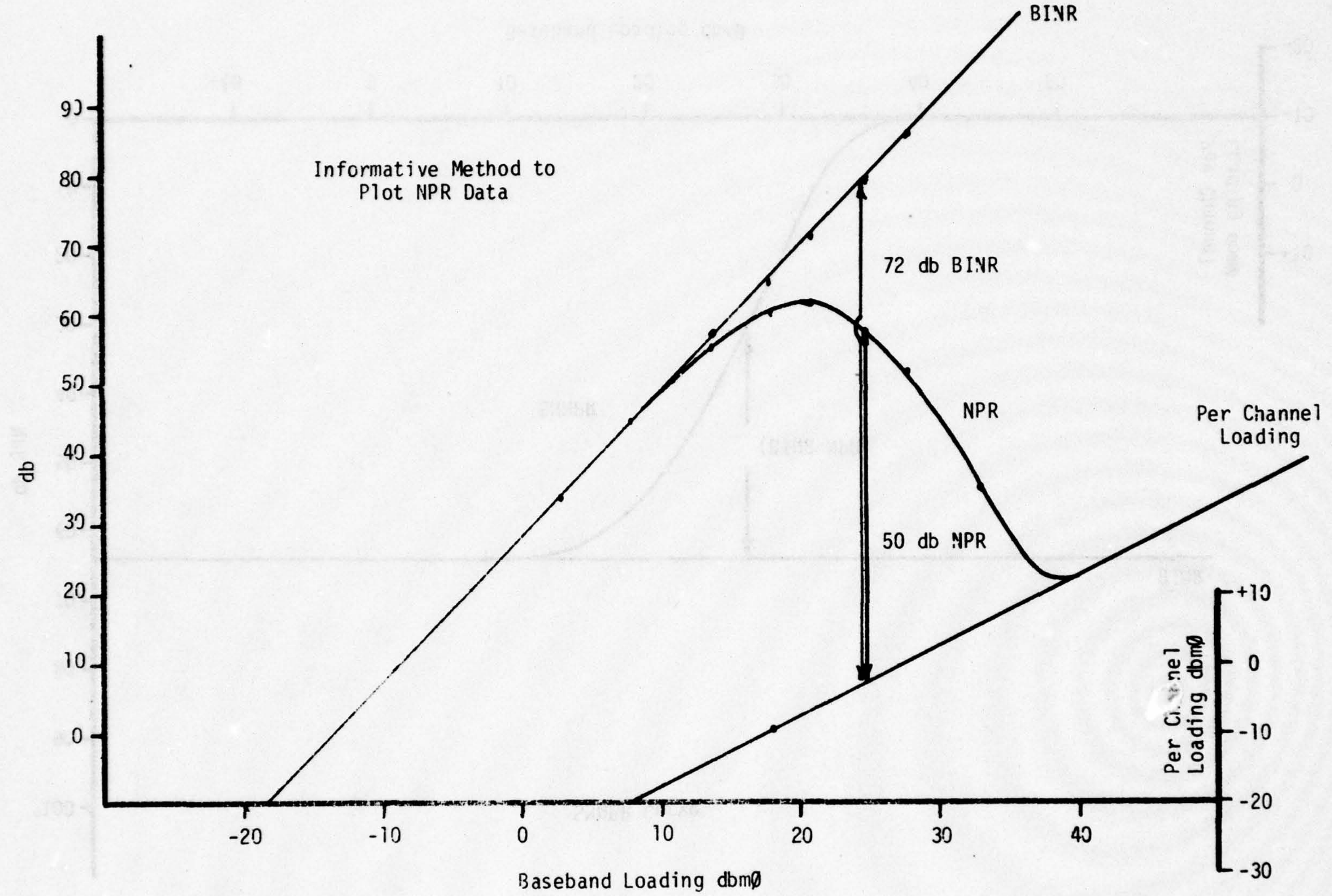
Unfortunately, during the proof test, the multiplex was noisy, although there did not appear to be any significant increase in intermodulation. Thus, to prove the correlation of the composite S/N curve with the actual audio channel noise performance, during the test an accomodation was required. This adjustment was a replotting of the mux BINR curve to the actual measured value.

This does not change the procedures, but does require the graphical addition of three curves (radio SNNPR + mux BINR + Mux IM).



Modified NPR
Curve Presentation
BINR
NPR
db
90
80
70
60
50
40
30
20
10
0
-20
-10
0
10
20
30
40
Baseband Loading dbmØ
Per Channel
Loading dbmØ
20
10
0
-10
-20

Fig. III-1



Informative Method to
Plot NPR Data
BINR
72 db BINR
NPR
50 db NPR
Per Channel
Loading
db
90
80
70
60
50
40
30
20
10
0
-20
-10
0
10
20
30
40
Baseband Loading dbmØ
Per Channel
Loading dbmØ
+10
0
-10
-20
-30

Fig. III-2

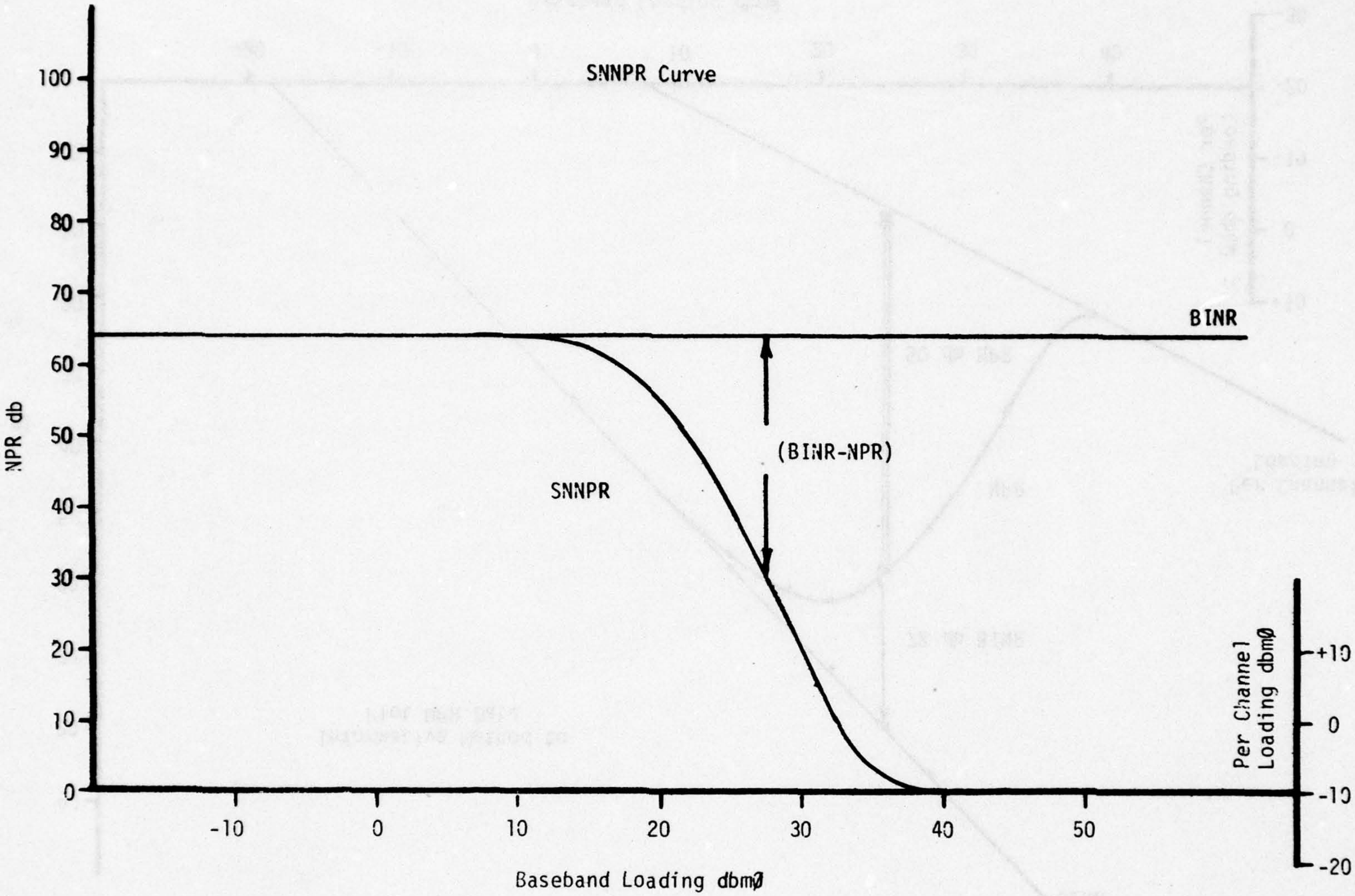

SNNPR Curve
BINR
(BINR-NPR)
SNNPR
NPR db
100
90
80
70
60
50
40
30
20
10
0
-10
0
10
20
30
40
50
Baseband Loading dbmØ
Per Channel
Loading dbmØ
+10
0
-10
-20

Fig. III-3

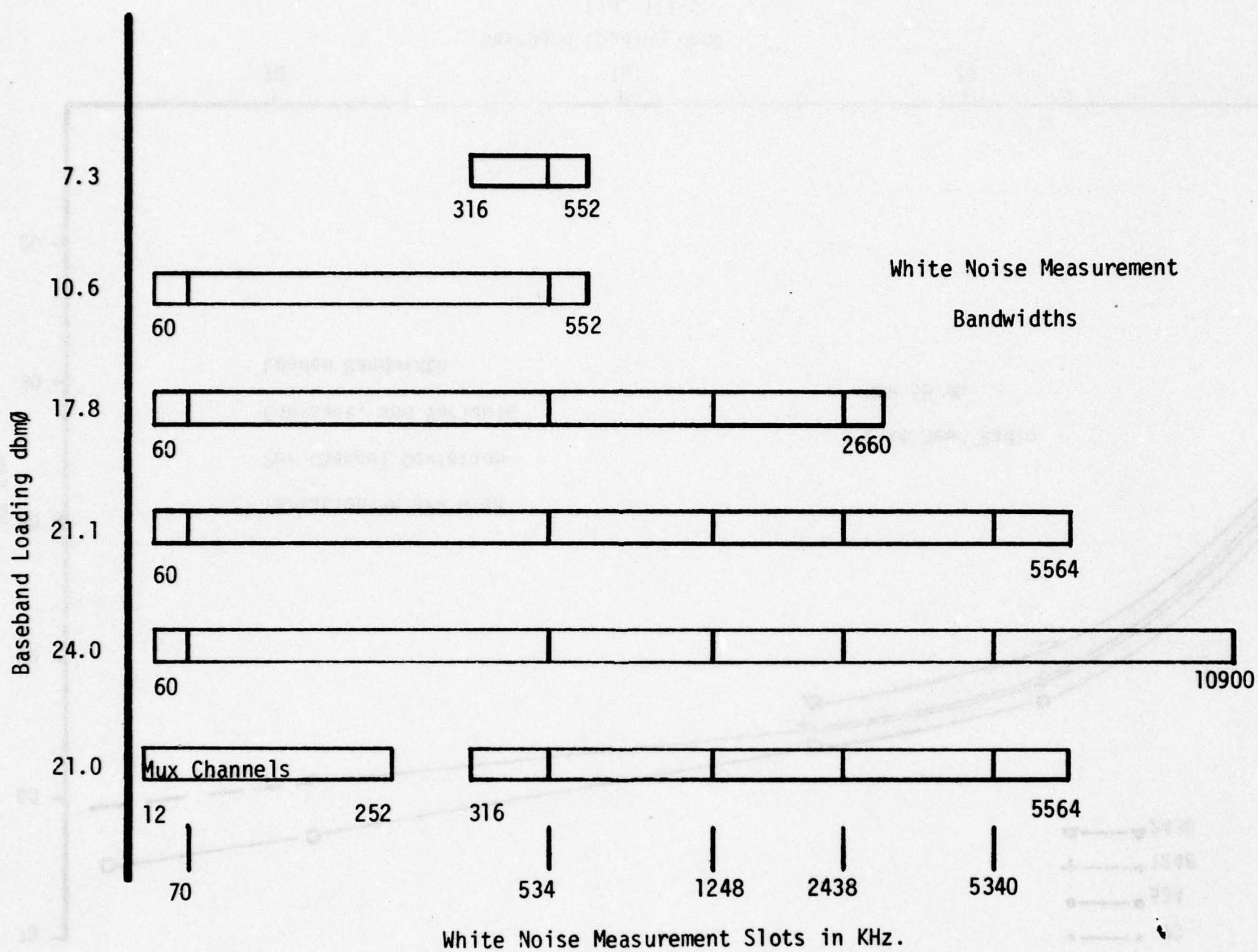
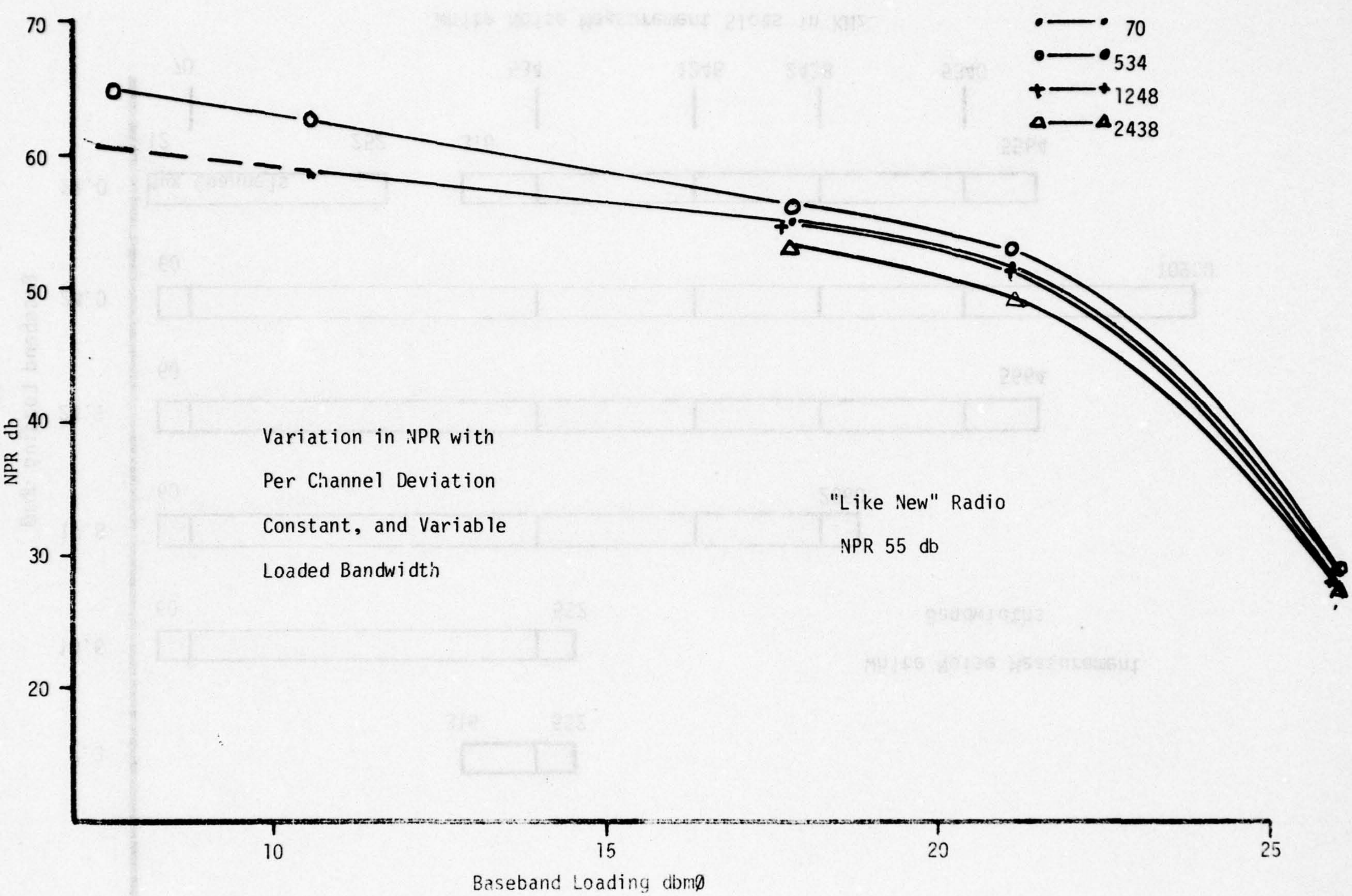

White Noise Measurement
Bandwidths
Baseband Loading dbm0
7.3
10.6
17.8
21.1
24.0
21.0
316
552
60
552
60
2660
60
5564
60
10900
Mux Channels
12
252
316
5564
70
534
1248
2438
5340
White Noise Measurement Slots in KHz.

Fig. III-4



70
60
50
40
30
20
NPR db
10
15
20
25
Baseband Loading dbm∅
70
534
1248
2438
Variation in NPR with
Per Channel Deviation
Constant, and Variable
Loaded Bandwidth
"Like New" Radio
NPR 55 db

Fig. III-5

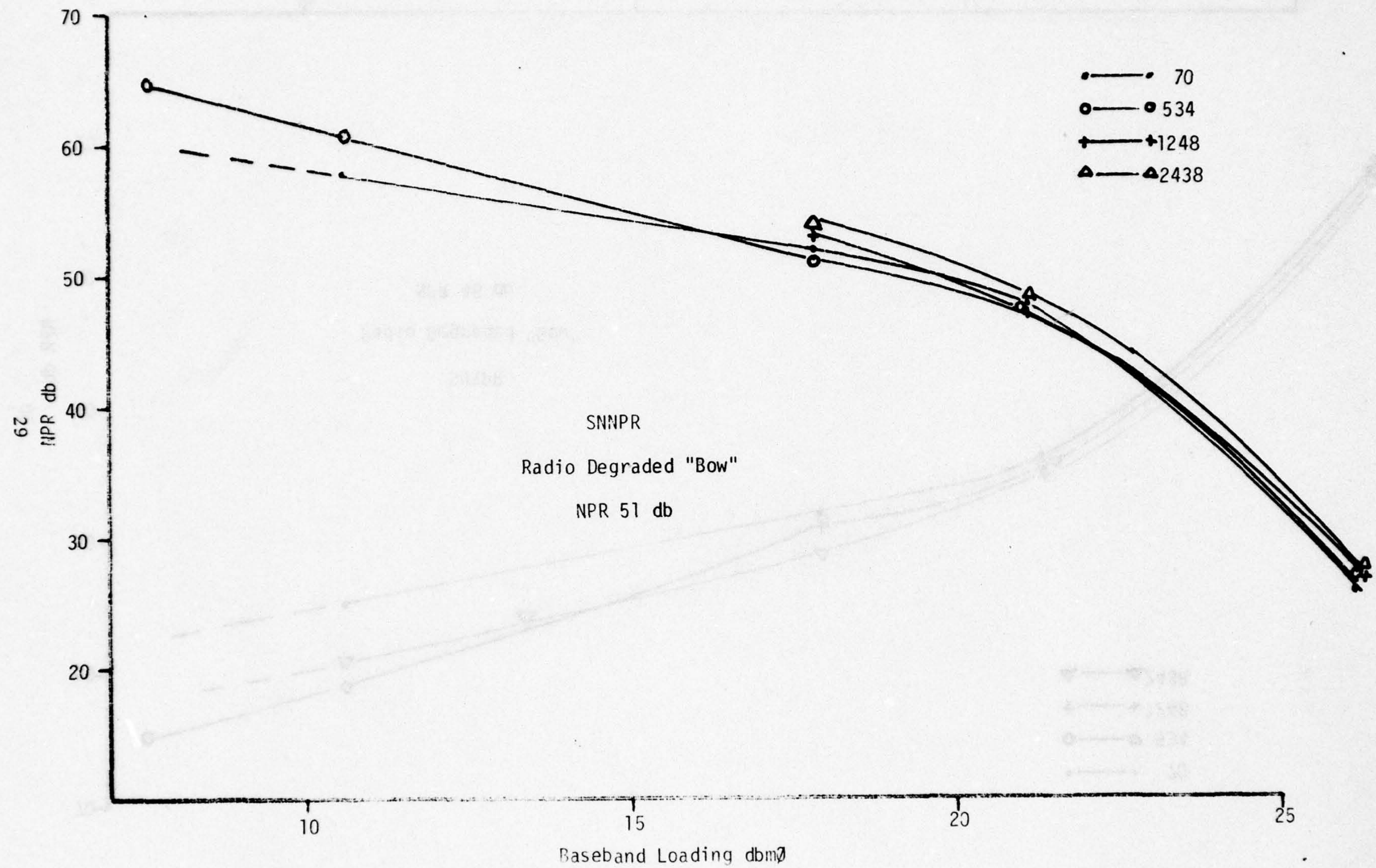

70
60
50
40
30
20
NPR db
10
15
20
25
Baseband Loading dbm0
70
534
1248
2438
SNNPR
Radio Degraded "Bow"
NPR 51 db

Fig. III-6

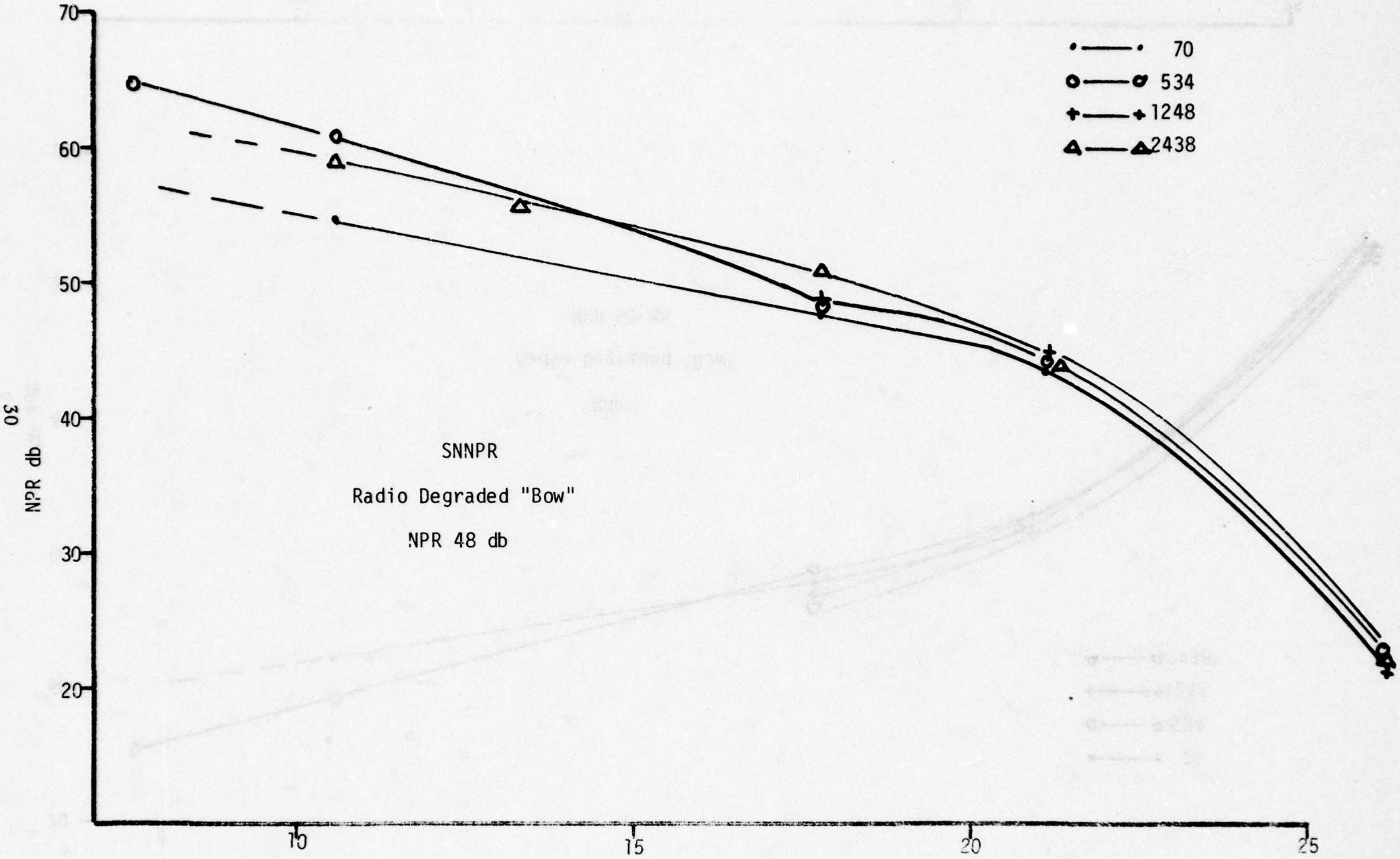

70
534
1248
2438
SNNPR
Radio Degraded "Bow"
NPR 48 db
NPR db
Baseband Loading dbmØ
70
60
50
40
30
20
10
15
20
25

Fig. III-7

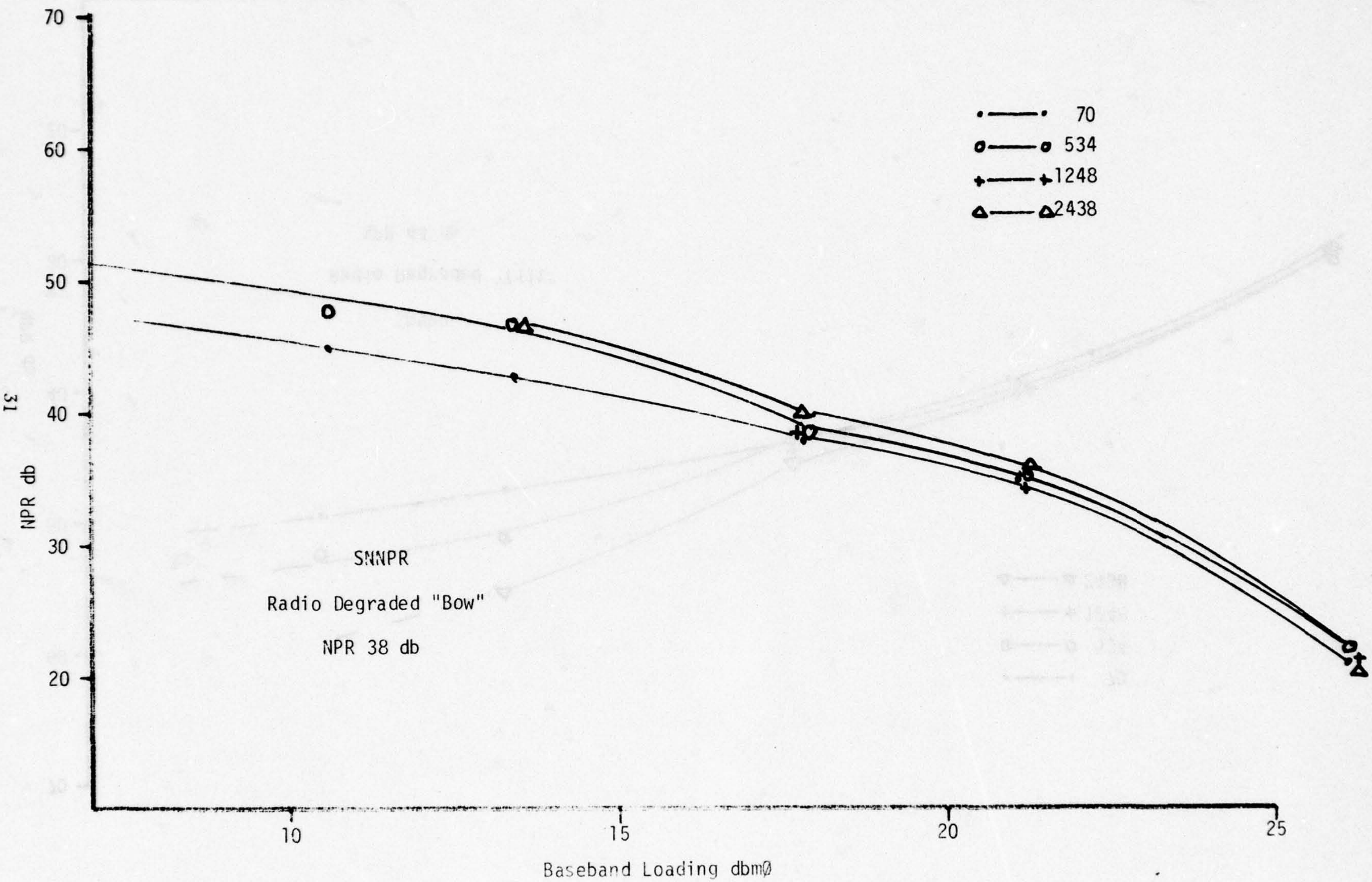

70
534
1248
2438
NPR db
70
60
50
40
30
20
SNNPR
Radio Degraded "Bow"
NPR 38 db
10
15
20
25
Baseband Loading dbmØ

Fig. III-8

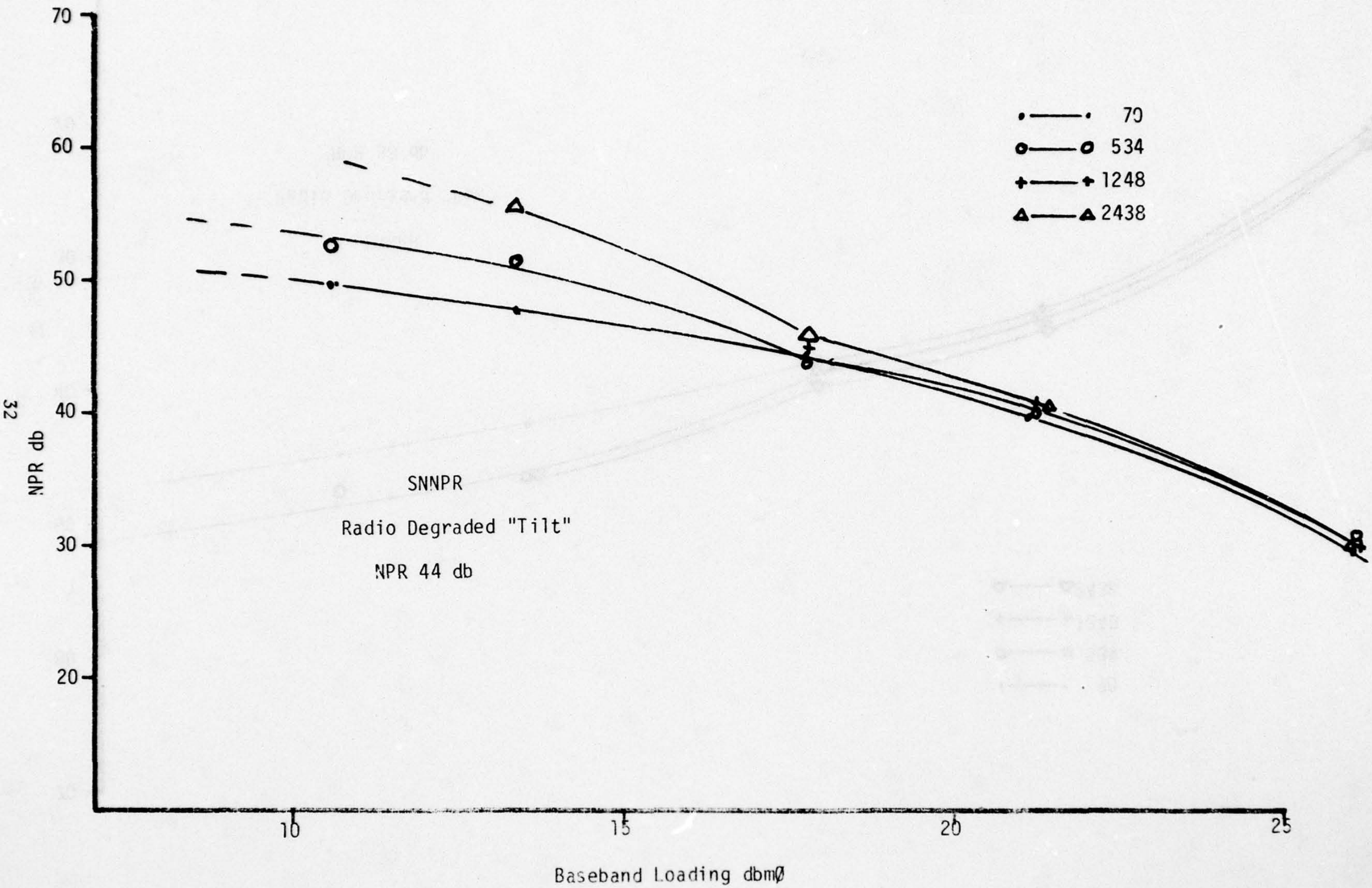

70
60
50
40
30
20
NPR db
10
15
20
25
70
534
1248
2438
SNNPR
Radio Degraded "Tilt"
NPR 44 db
Baseband Loading dbmØ

Fig. III-9

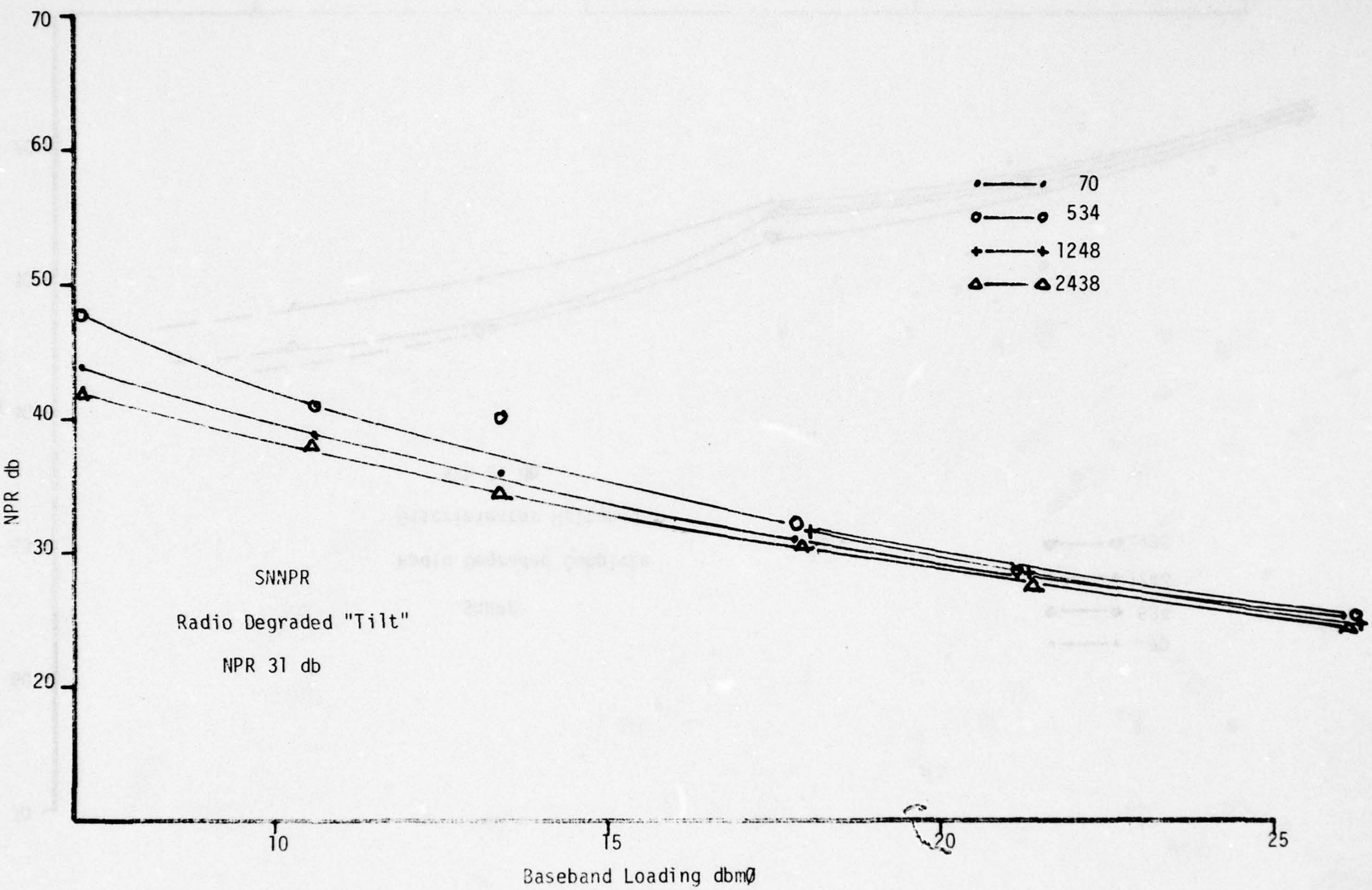

70
60
50
40
30
20
NPR db
10
15
20
25
Baseband Loading dbm0
70
534
1248
2438
SNNPR
Radio Degraded "Tilt"
NPR 31 db

Fig. III-10

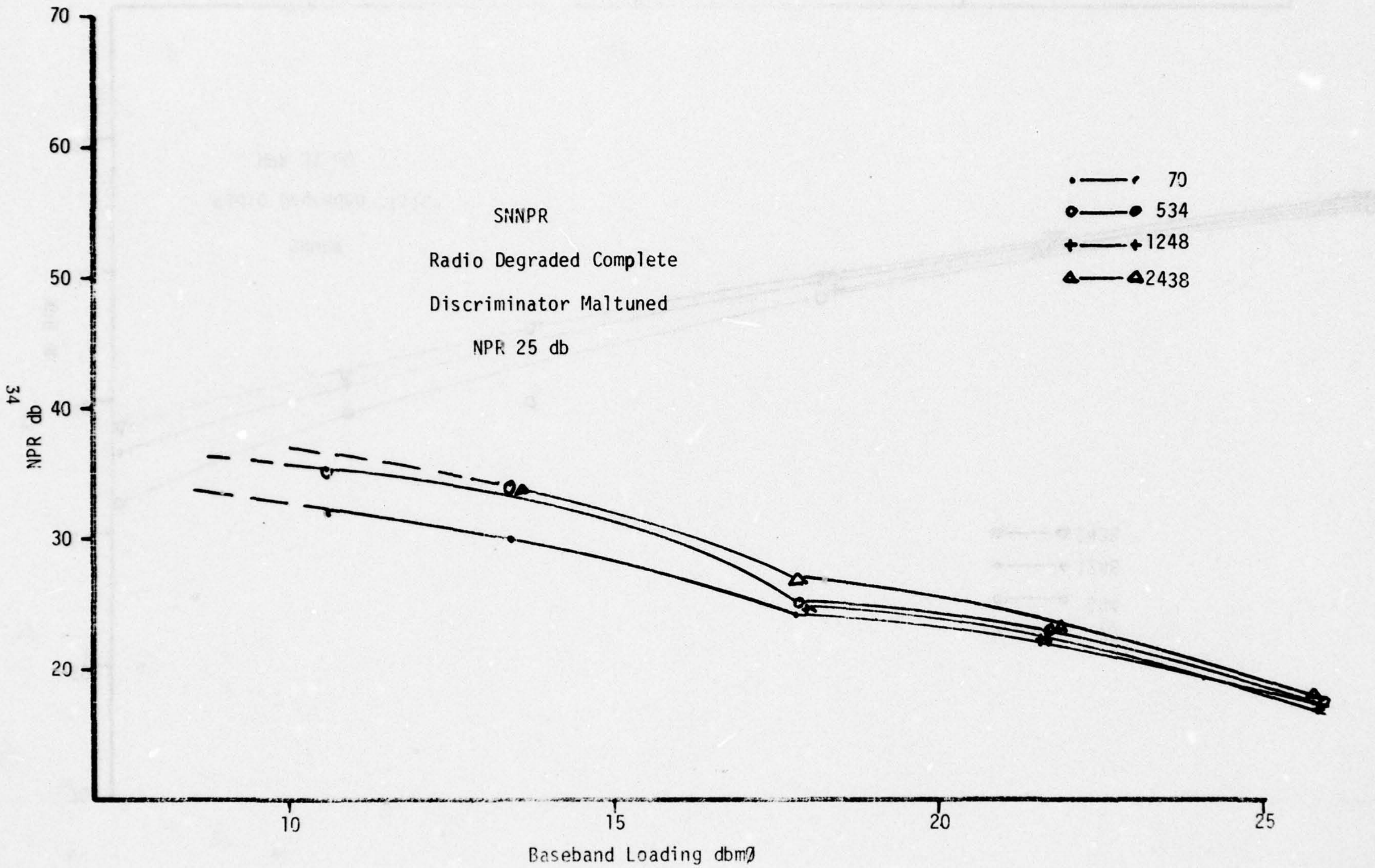

SNNPR
Radio Degraded Complete
Discriminator Maltuned
NPR 25 db
70
534
1248
2438
NPR db
70
60
50
40
30
20
10
15
20
25
Baseband Loading dbm∅

Fig. III-11

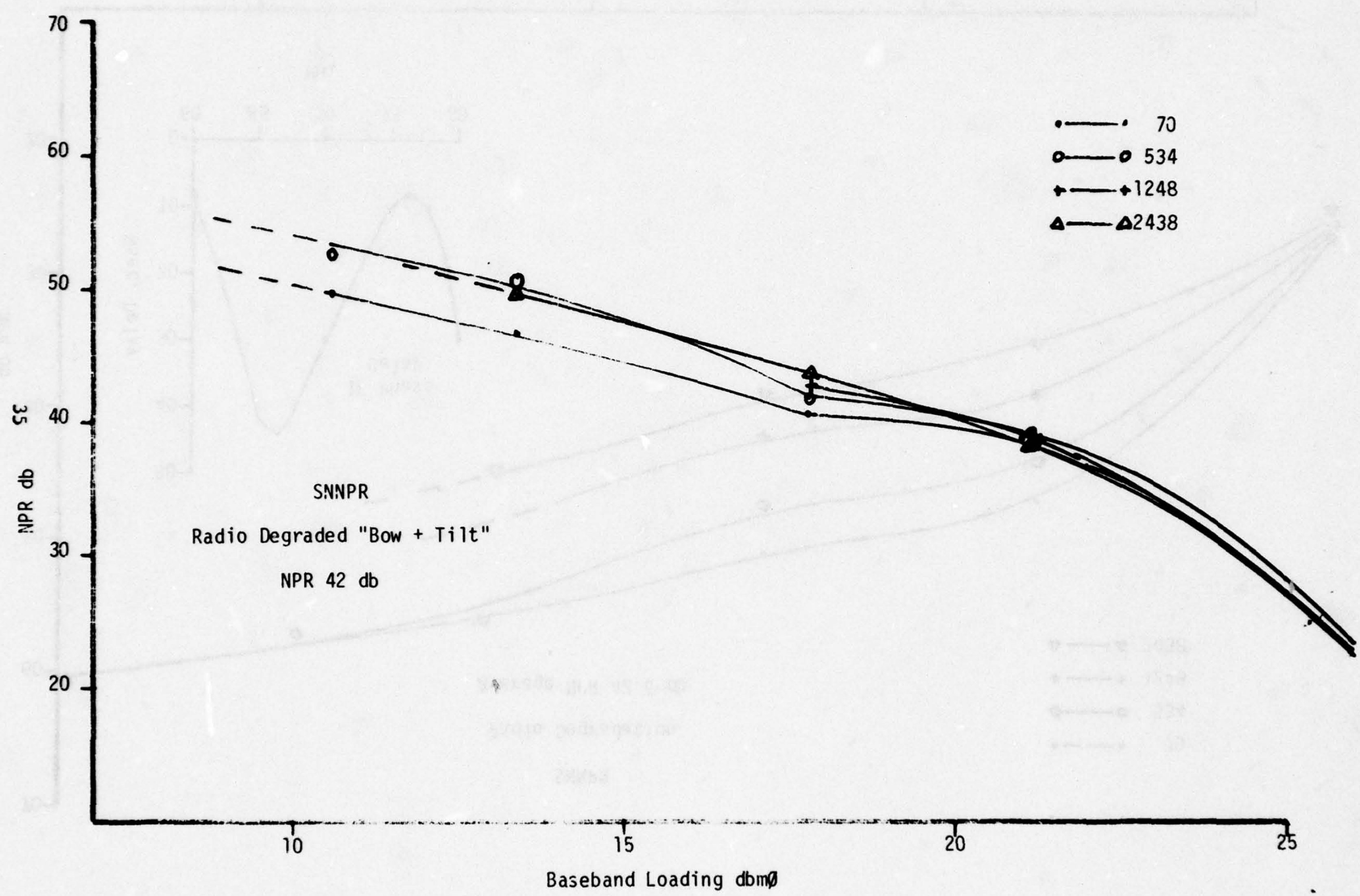

70
534
1248
2438
SNNPR
Radio Degraded "Bow + Tilt"
NPR 42 db
NPR db
35
70
60
50
40
30
20
10
15
20
25
Baseband Loading dbmØ

Fig. III-12

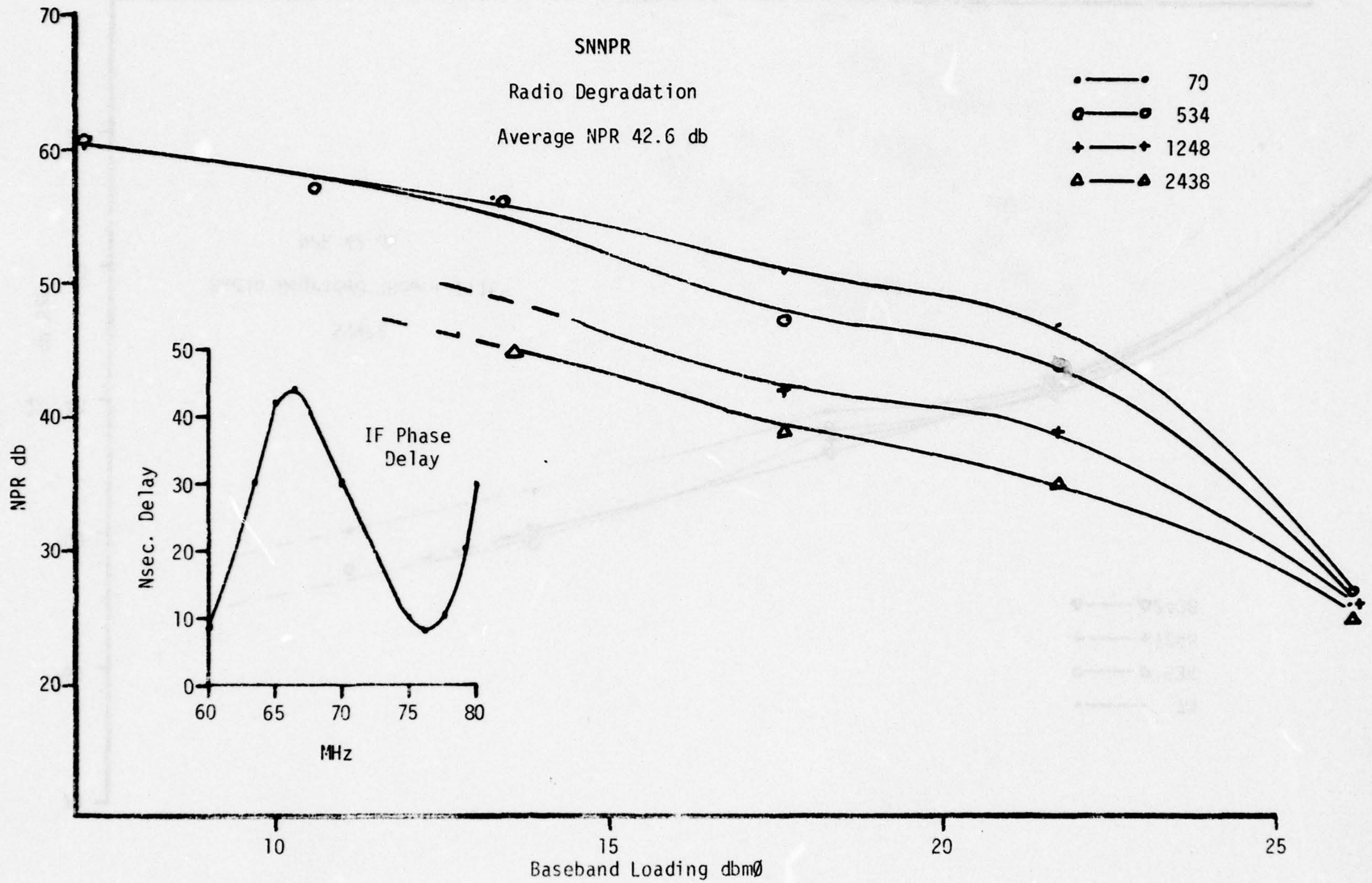

SNNPR
Radio Degradation
Average NPR 42.6 db
70
534
1248
2438
NPR db
70
60
50
40
30
20
10
15
20
25
Baseband Loading dbmØ
IF Phase Delay
Nsec. Delay
50
40
30
20
10
0
60
65
70
75
80
MHz

Fig. III-13

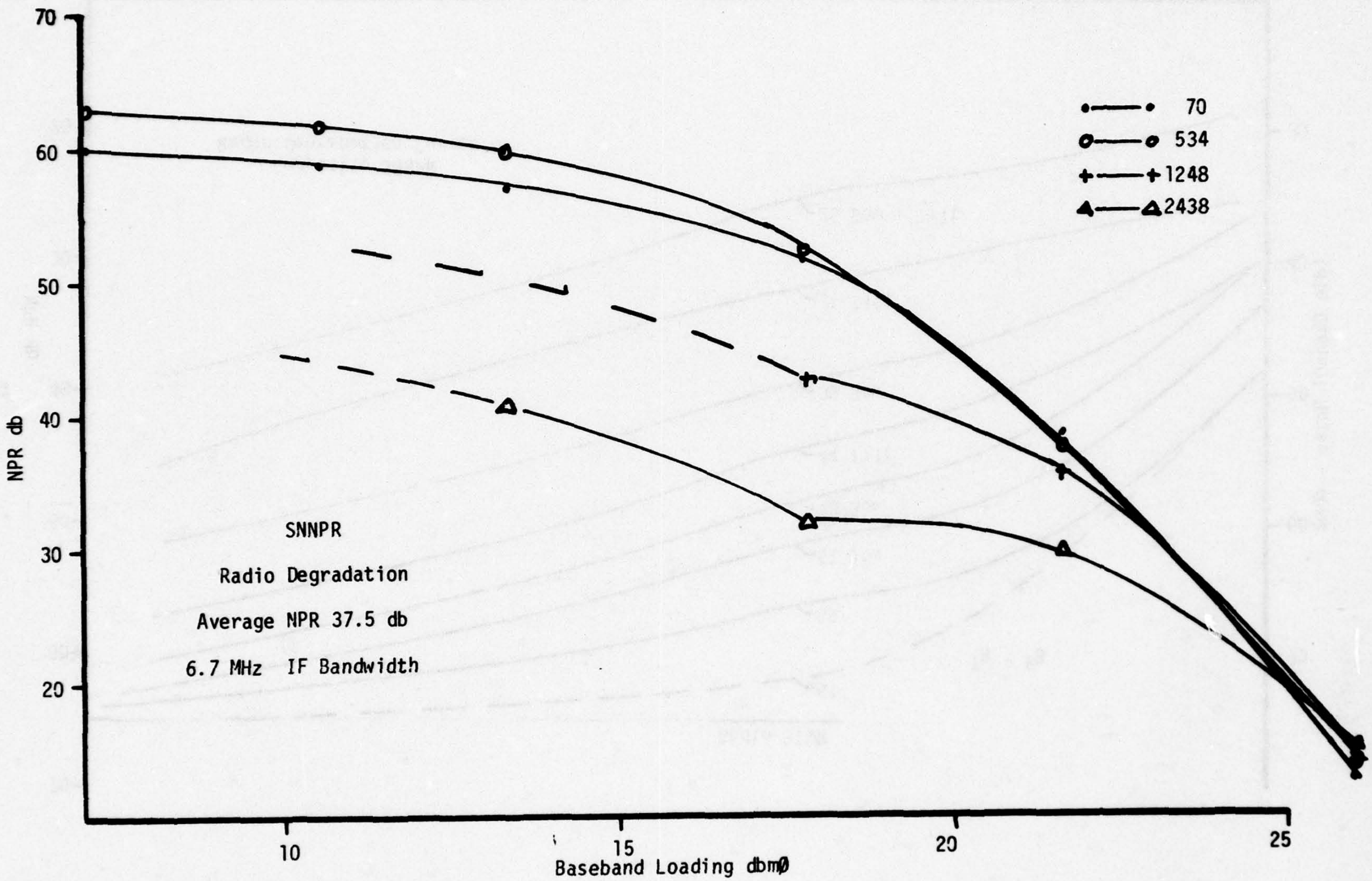
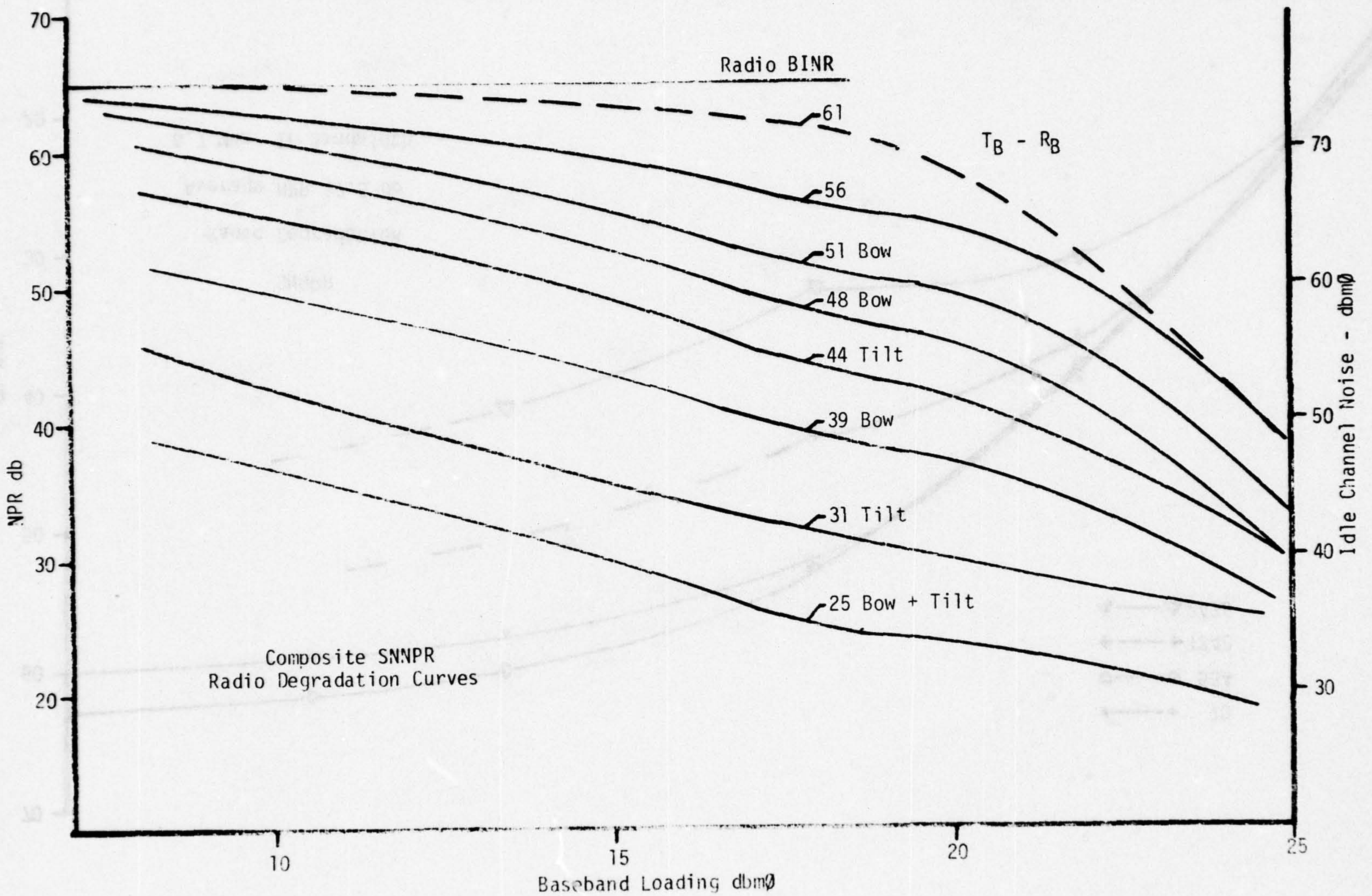

70
534
1248
2438
SNNPR
Radio Degradation
Average NPR 37.5 db
6.7 MHz IF Bandwidth
NPR db
Baseband Loading dbm0
10
15
20
25
70
60
50
40
30
20

Fig. III-14



NPR db
70
60
50
40
30
20
Radio BINR
61
56
51 Bow
48 Bow
44 Tilt
39 Bow
31 Tilt
25 Bow + Tilt
T_B - R_B
Composite SNNPR
Radio Degradation Curves
Idle Channel Noise - dbmØ
70
60
50
40
30
10
15
20
25
Baseband Loading dbmØ

Fig. III-15

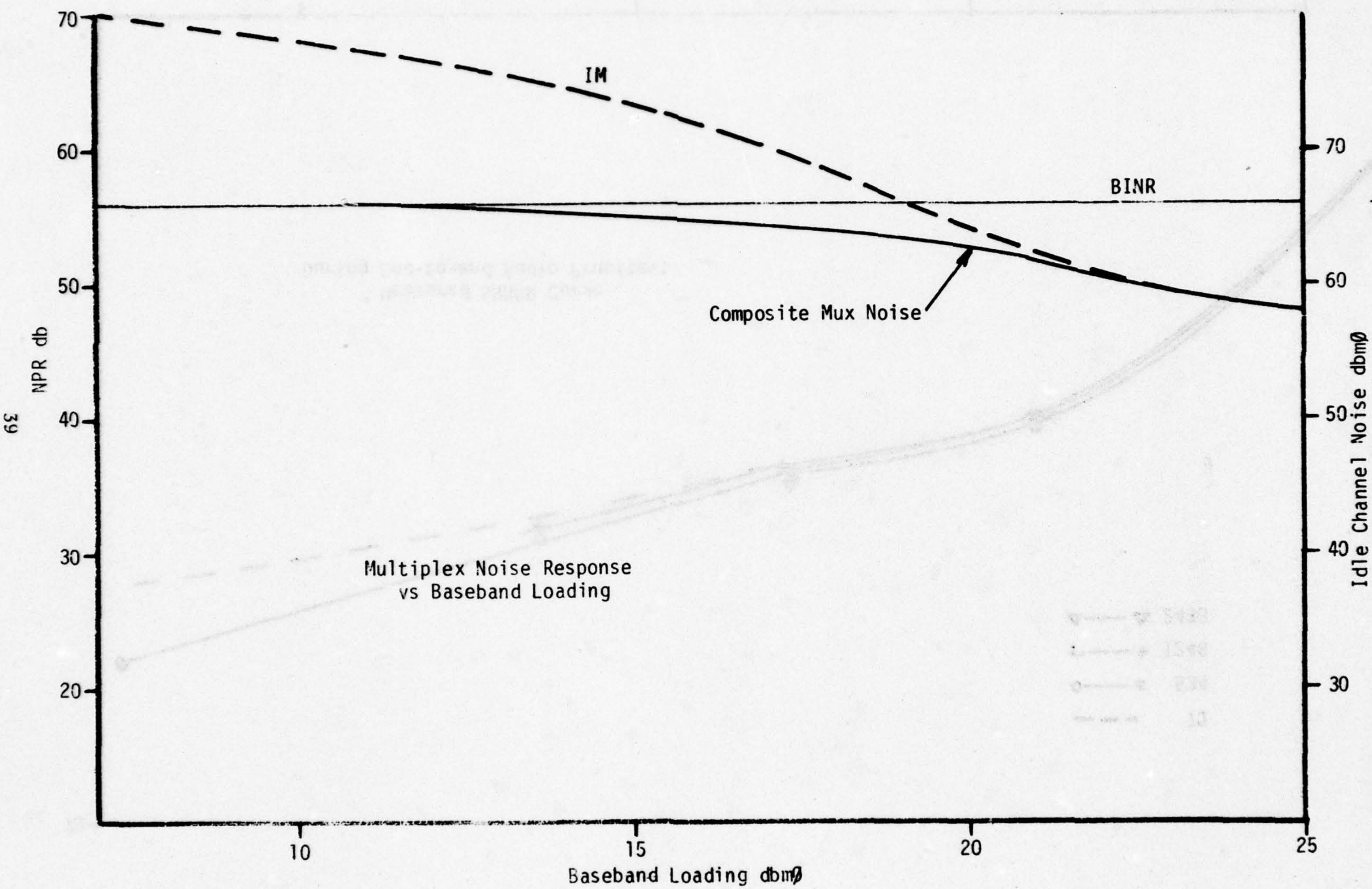
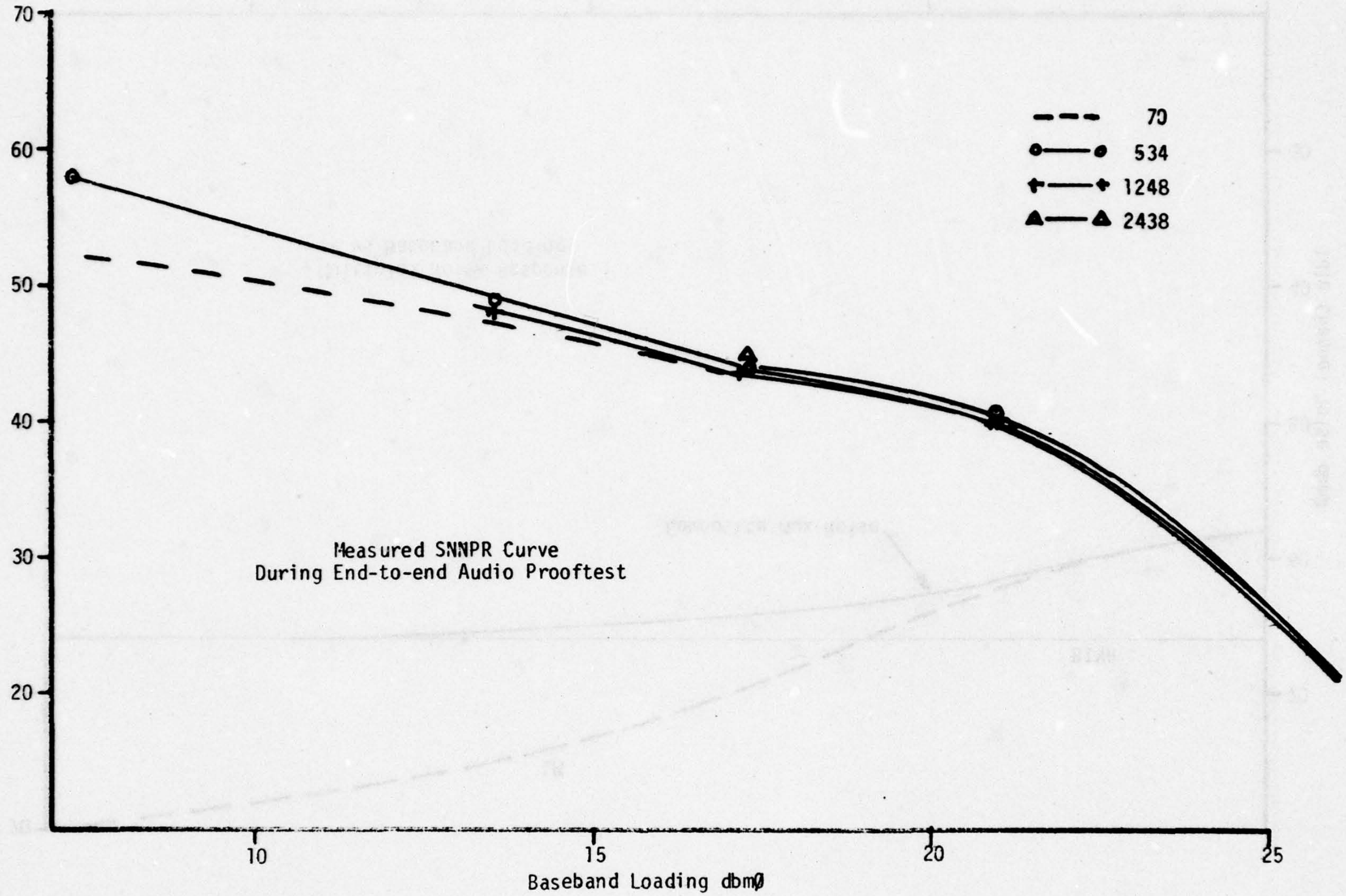

IM
BINR
Composite Mux Noise
Multiplex Noise Response
vs Baseband Loading
NPR db
Idle Channel Noise dbmØ
70
60
50
40
30
20
10
15
20
25
Baseband Loading dbmØ

Fig. III-16



70
60
50
40
30
20
10
15
20
25
70
534
1248
2438
Measured SNNPR Curve
During End-to-end Audio Prooftest
Baseband Loading dbm0

Fig. III-17

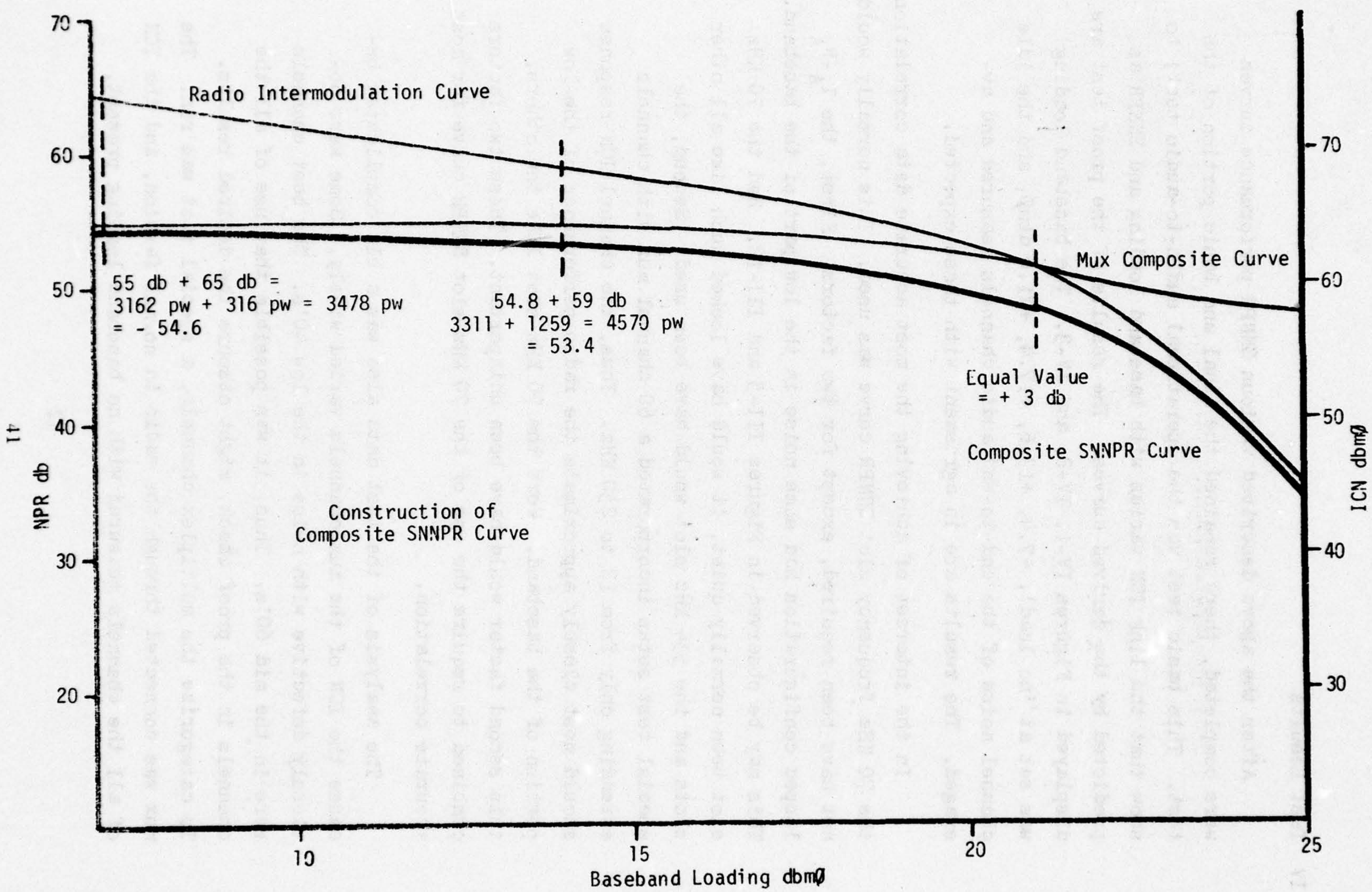

Radio Intermodulation Curve
Mux Composite Curve
55 db + 65 db =
3162 pw + 316 pw = 3478 pw
= - 54.6
54.8 + 59 db
3311 + 1259 = 4570 pw
= 53.4
Equal Value
= + 3 db
Composite SNNPR Curve
Construction of
Composite SNNPR Curve
NPR db
ICN dbm∅
Baseband Loading dbm∅
70
60
50
40
30
20
10
15
20
25

Fig. III-18

IV Test Results

After the above described various SNNPR performance curves were completed, there remained the final and basic portion of the test. This basic test was the operational audio-to-audio test; to show that the link ICN varies with baseband loading and SNNPR as predicted by the derived curves. The results of the proof test are displayed in Figures IV-1, IV-2, and IV-3. The baseband loading was set at 'no load', +7.4, +13.6, +17.4, +21.0 dbm∅, and the idle channel noise of the end-to-end audio channels measured and averaged. The results are in agreement with those expected.

In the interest of achieving the most accurate data correlation, the 70 KHz frequency slot SNNPR curve was used. This normally would not have been required, except for two factors. First, the T_A-R_A looped configuration had some noise in the low part of the baseband. This may be observed in Figures III-5 and III-12, Had the 70 KHz slot been normally quiet, it would have looked much like all other slots and the 534 KHz slot would have been used. Second, the special test setup incorporated a 60 channel mux with channels extending only from 12 to 250 KHz. Thus, the channel ICN response should most closely approximate the radio performance of the low portion of the baseband. Were the 70 KHz slot like the others, this second factor would have been unimportant. These two factors combined to require the use of the 70 KHz slot SNNPR curve for most accurate correlation.

The analysis of the test data also was a bit complicated because the ICN of the mux channels varied widely. Some were obviously defective with noise in the low 40's. The best channels were in the mid 60's, Thus, it was possible that use of all the channels in the proof check, might obscure the desired results. To categorize the multiplex channels, a special test was run. The mux was connected through the radio in normal fashion, and the ICN of all the channels measured with no baseband loading present.

The channel noise was spread over a rather wide range. Sixteen of the sixty channels had ICN values noisier than -53 dbm∅ - obviously unusable. Thirty-eight channels were -60 dbm∅ or noisier. Fifty-five channels were -64 dbm∅ or noisier. As a result, three slightly different analyses were conducted. The first proof test used most of the channels, while ignoring only those with unloaded baseband ICN -56.5 dbm∅ or noisier. The mux channel noise averaged -59.8 dbm∅, and the composite curve reflects this high mux BINR. In this test, the ICN was averaged for the remaining 44 channels. See Figure IV-1. The triangles plot the actual test measured values at the five baseband loading levels. All measured values agree within ± 1.5 db of the curve predicted values.

In the second case, Figure IV-2, 22 of the quieter channels, -60.5 dbm∅ or better, were used, and the composite curve redrawn to reflect the quieter mux BINR. The agreement of all points was within ± 1.5 db.

In the last example, Figure IV-3, only 5 of the 60 channels, those -65.0 dbm∅ or better were used. In this highly undersampled case, with the mux BINR redrawn, all proof points are within ± 1.5 db again, except the 3.2 db overload condition that was +2.5 db.

No fully satisfactory explanation is evident to explain the lack of appropriate measured and predicted ICN degradation at the 4 db overload position. It is possible that some unnoticed band limiting in the special mux/noise test set input circuitry to the transmitter, or some malfunction in the white noise test set filter associated with this highest baseband loading, or other factors effectively reduced the actual loading on the link by 1 db. If this 1 db underloading occurred, the observed ICN values would check within ± 1 db of the predicted values. Such explanation is probably correct, but is not a demonstrable fact. However, the baseband overload condition is already an operational alert, and the error unimportant. The ± 1.5 db accuracy over the entire useful operational range of DCS loadings is adequate, has been demonstrated, and is within normal field test measurement accuracy.

Clearly, the test results agree quite closely with those expected. The unusual test configuration, excess cabling, extra terminations, etc., did not appear to have much adverse affect on the results.

Thus, it is reasonable to address the next question; how to construct the operationally useful family of SNNPR curves.

In order to view the whole baseband loading informative range of values, a review of Figures III- 1 & 2, is helpful. It is clear that at light loadings, the curves must be asymptote to the BINR value. At heavy overloads, the asymptote is the per channel loading signal level itself. Figure IV-4, displays this dual convergence in the SNNPR format. Figure III-15, shows the convergence in the SNNPR curves in the loading range of interest.

Figure IV-5, displays the maximum spread of the SNNPR for the various frequency slots at each introduced degradation value. It is clear that the spread of slot values is reasonable. Figure IV-6, is a plot of the 'average' of the various frequency slots. This average approximates the 534 KHz slot for this test and the 534 slot will be used as the single average curve for the rest of this analysis.

Figure IV-7, is an analysis of the shape of the SNNPR curves over the range of interest. Since the NPR of a radio is specified at full CCIR or DCA baseband loading, it is obvious that this full load point is the unity reference. That is, a 5 db drop in NPR at full load represents a 5 db change in the measured NPR value. The SNNPR values are identical to the NPR values at this full loading, so they too are db for db. At lighter baseband loadings of 7 db below full load, for example, each SNNPR curve degrades, but 83% (in db) of the amount measured at full load. Thus, a 5 db degradation at full load results in a SNNPR change from 55 to 50 db. This same 5 db degradation results in a 4 db drop of SNNPR performance from 61 to 57 db at a loading of 7 db below full load. Similarly, the degradation ratio is 89% at a baseband loading 3db below full load.

It is clear that SNNPR distortions in excess of 35 db are of little practical use, since the major problems with the radio/mux equipment would already be clearly evident, so no curves below 35 db NPR are examined further.

Figure IV-8, is a slightly smoothed family of SNNPR curves from 55 to 35 db. It is recognized that at very extreme degradations, such as 25 db, the actual measured curves do not quite follow the smoothed configurations. Measured values at +21 dbmØ or higher were subject to known instrumentation and bandwidth difficulties. The smoothed curves are estimated closer to expected values. This is not a matter of great concern, since these two types of deteriorations are already Red-Red and are unambiguous.

Figure IV-9, is the combined radio plus multiplex link family of curves, constructed as explained previously, and using the best mux performance achieved during the test - that is, mux BINR of -66 dbmØ as displayed in Figure III-16. A well maintained mux BINR would be -70 dbmØ.

An obvious operational question at this point would be to examine this final composite SNNPR curve with regard to the actual test data and to contrast the SNNPR with the present DCS PMP reporting. Figure IV-10, portrays the test data taken when only good channels were used - that is, where channel BINR averaged -64.5 dbmØ. This figure portrays the degraded link operation with the link measured NPR 42 db and the mux thus degraded. The ICN -61.5 dbmØ at a loading 10 db light would indicate an NPR of 41 db. The extrapolated ICN would be -51.5 dbmØ. The actual measured ICN was -52.3 dbmØ as plotted by the inverted triangle. The NPR agreement is good and the mux noise introduces part of the 1 db error. Clearly, the link is Red-Red. In the case of the present PMP reporting, the ICN of -61.5 dbmØ would be Green. Management clearly would not get proper information from the PMP, and thus would ignore a highly degraded link. The SNNPR status is correct to within ± 1 db.

Figure IV-11, portrays the test data taken where radio NPR was still 42 db, and the multiplex BINR was heavily degraded. This was accomplished by averaging the 44 channels with no load ICN of -59.8 dbmØ or quieter. The test bed ICN measured -57.5 dbmØ at the 10 db light baseband loading. This measurement would extrapolate to an ICN of -44 dbmØ at full load conditions and would indicate an NPR of 34 db. The SNNPR clearly labels the link Red-Red. This link is over-estimated, since the NPR degradation was 42 db and the ICN measured -51.8 dbmØ, still, however, Red-Red. The error is 8 db in NPR and 8 db in ICN. The PMP rating of -57.5 in contrast, would only be a mid-Amber on DCS links, yet the link is very degraded. Even in this most extreme mux noise test case, rarely, if ever, encountered in DCS operational use, the PMP approach fails to strongly focus attention on a highly deteriorated path. The SNNPR correctly alerts management.

When channel measurements are made at light loadings, the SNNPR concept accurately assesses NPR degradations if the mux is reasonable or better. If the BINR of the radio or mux is excessive, this fact is indicated by over estimating the NPR deteriorations. This effect is less pronounced as the BINR degradations become less severe,and the resultant over-estimation reduces to the normal $\pm$ 1 db at all reasonable values.

The overall observation is: under no combination of path, radio, of mux deteriorations, is it possible, using the SNNPR concept, to miss detection of degradations or to under estimate a severe problem. The SNNPR concept is inherently weighted to emphasize the equipment basic noise problems. This is not considered a bad feature, since basic noise is normally an equipment failure related event and most often requires component replacement or repair to preclude subsequent complete hardware failure.

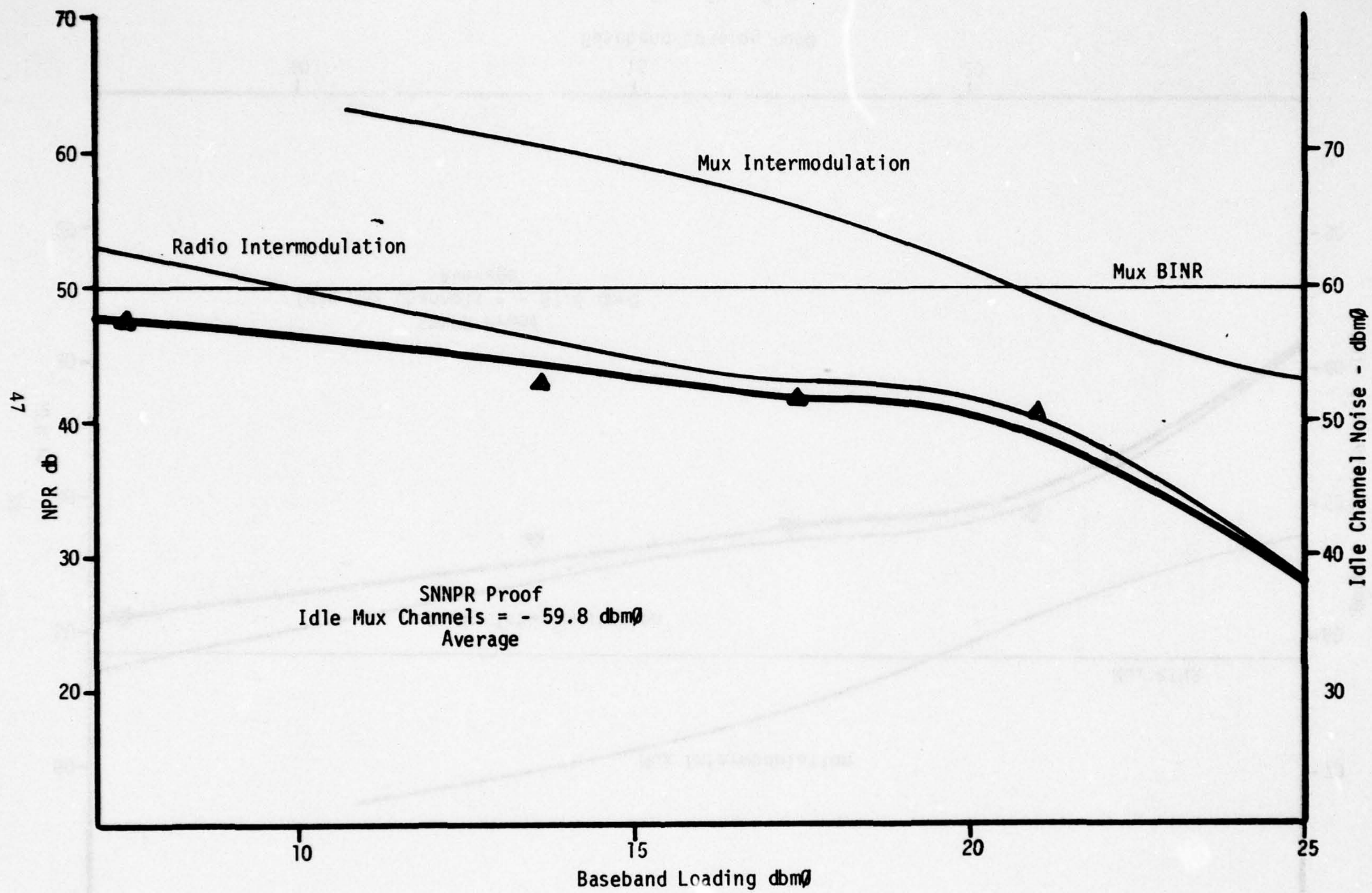

70
60
50
40
30
20
NPR db
Radio Intermodulation
Mux Intermodulation
Mux BINR
SNNPR Proof
Idle Mux Channels = - 59.8 dbmØ
Average
70
60
50
40
30
Idle Channel Noise - dbmØ
10
15
20
25
Baseband Loading dbmØ

Fig. IV-1

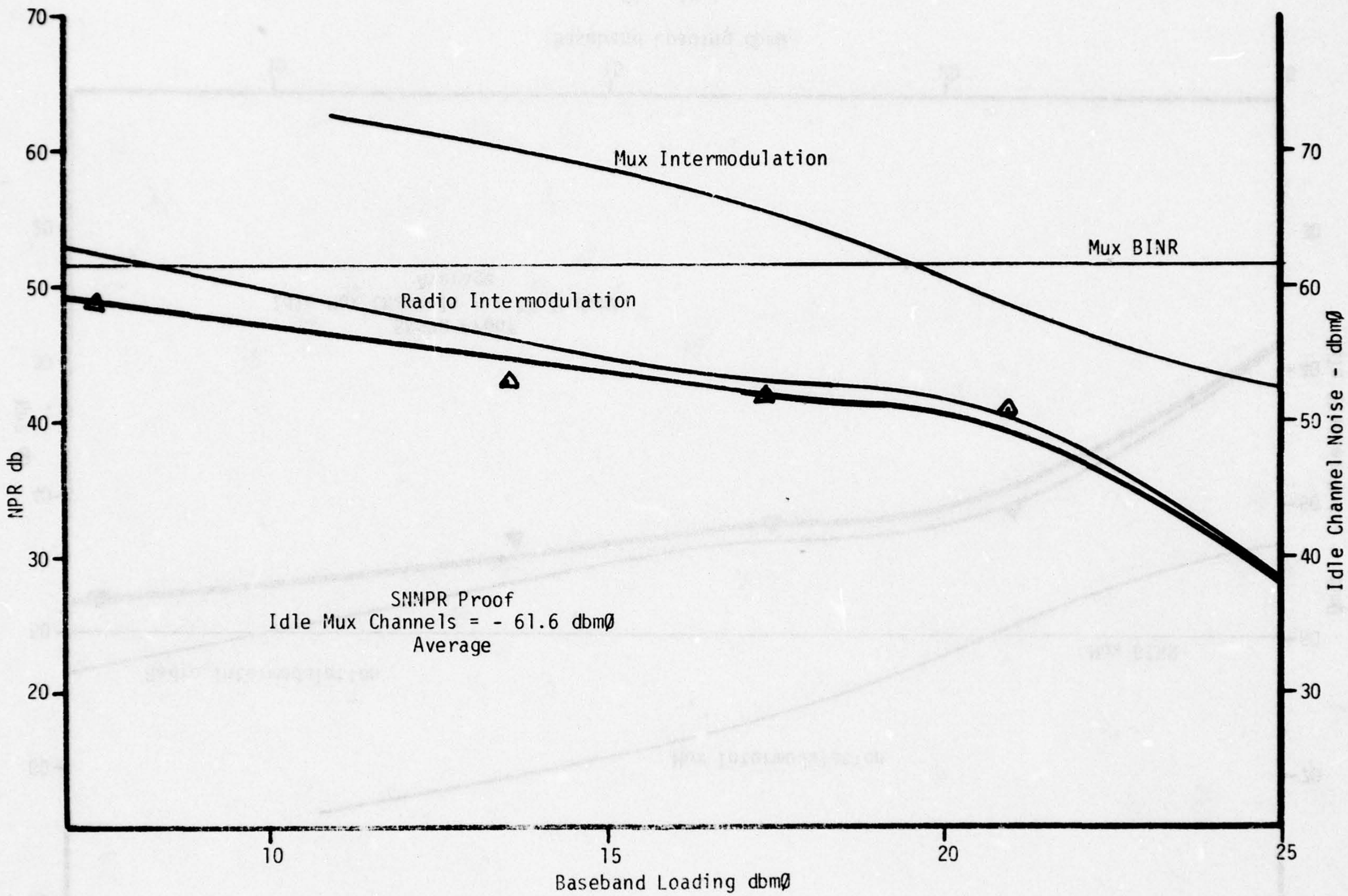
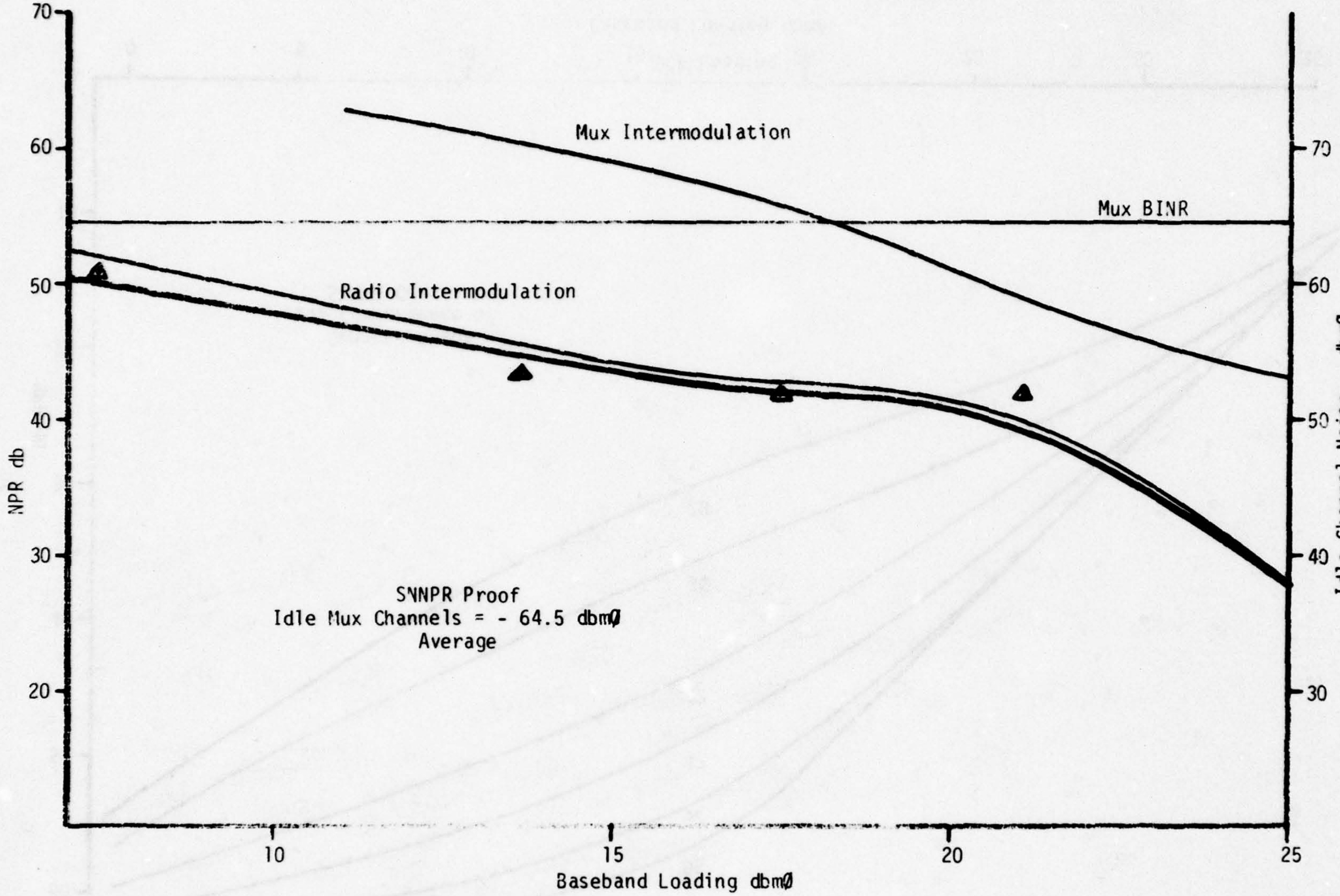
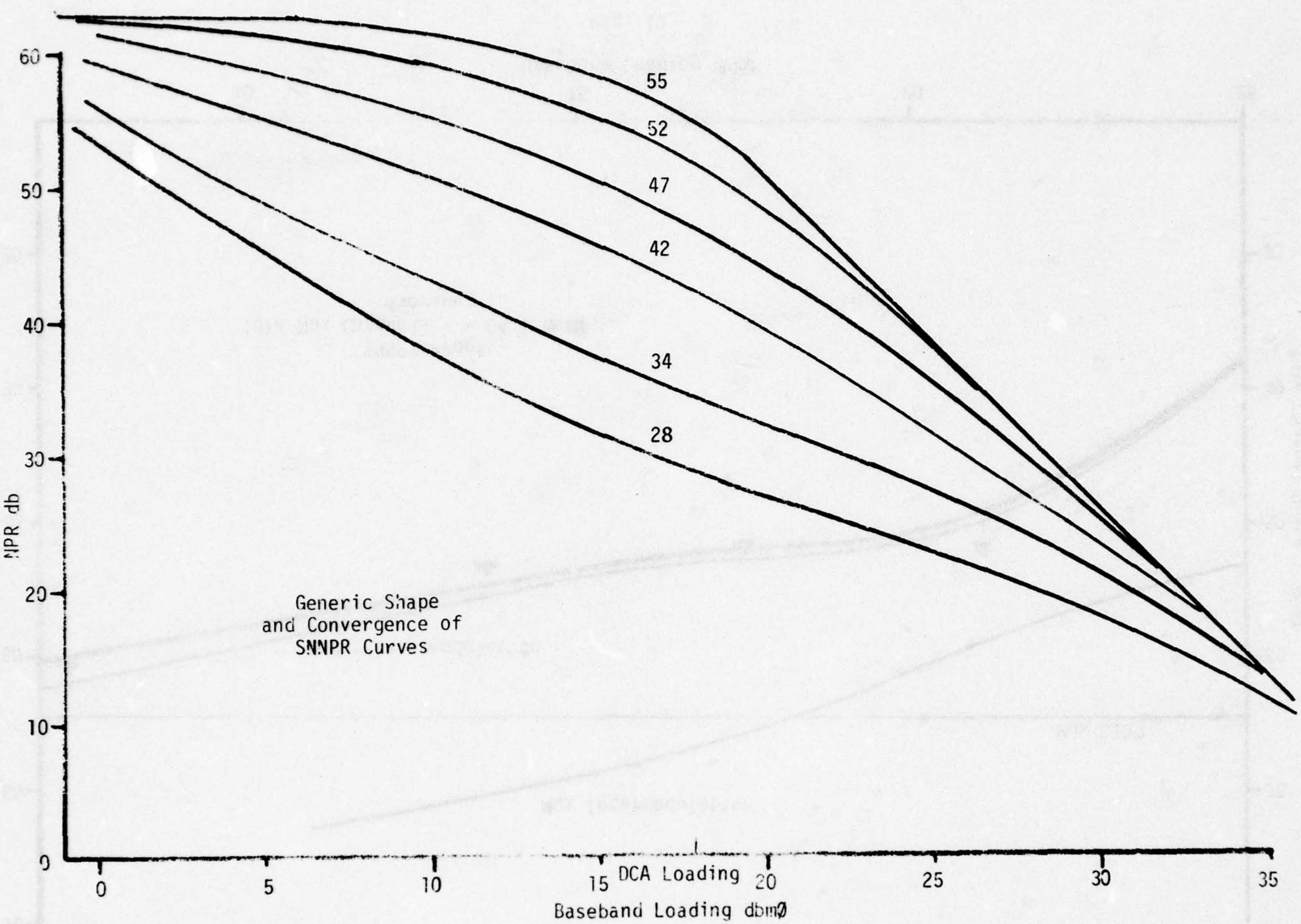

Mux Intermodulation
Mux BINR
Radio Intermodulation
SNNPR Proof
Idle Mux Channels = - 61.6 dbmØ
Average
NPR db
Idle Channel Noise - dbmØ
Baseband Loading dbmØ
70
60
50
40
30
20
10
15
20
25

Fig. IV - 2



Mux Intermodulation
Mux BINR
Radio Intermodulation
SNNPR Proof
Idle Mux Channels = - 64.5 dbm0
Average
NPR db
Idle Channel Noise - dbm0
Baseband Loading dbm0
70
60
50
40
30
20
10
15
20
25

Fig. IV - 3



NPR db
60
50
40
30
20
10
0
55
52
47
42
34
28
Generic Shape
and Convergence of
SNNPR Curves
0
5
10
15
20
25
30
35
DCA Loading
Baseband Loading dbmØ

Fig. IV - 4

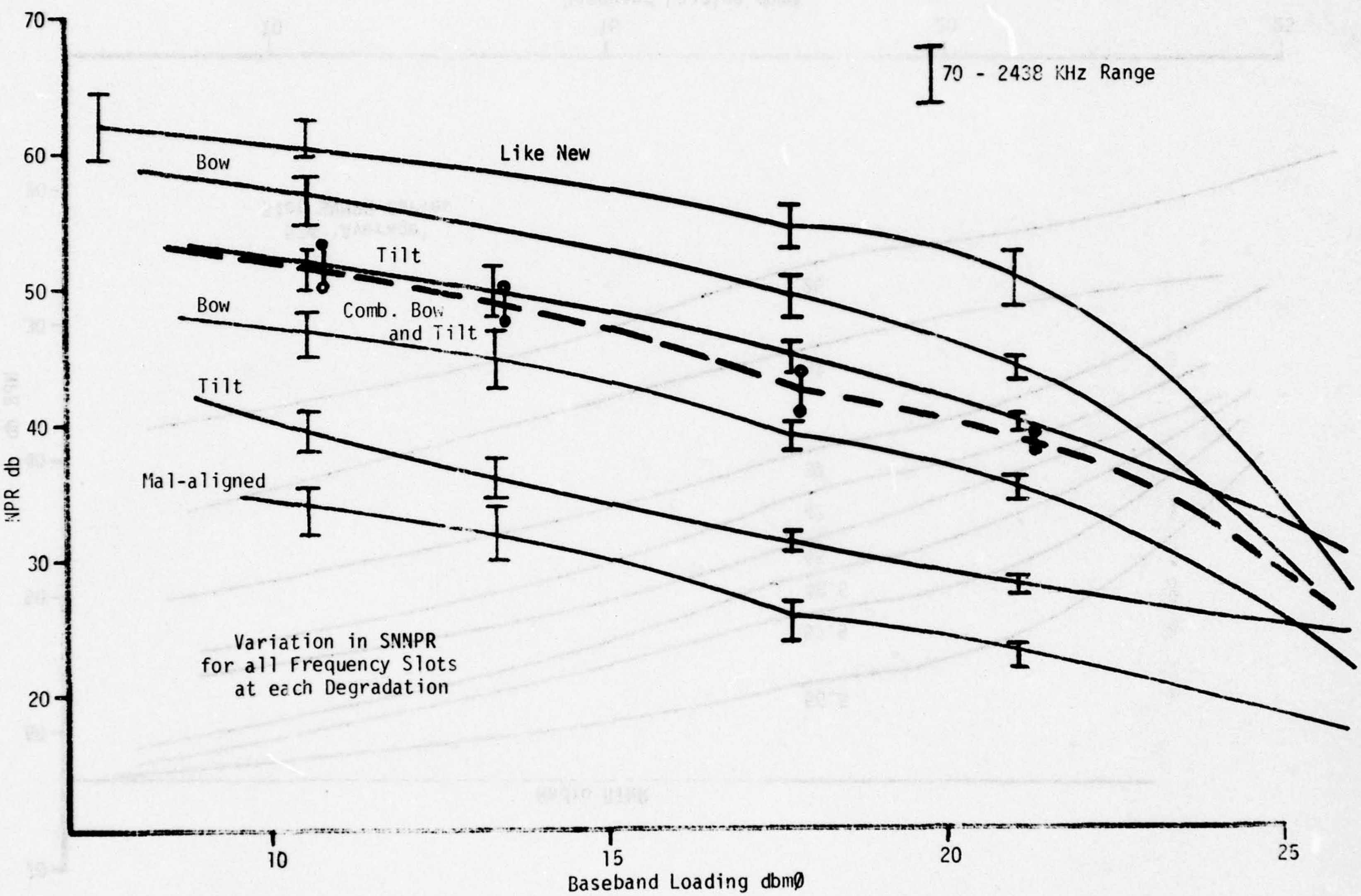

70 - 2438 KHz Range
Like New
Bow
Tilt
Bow
Comb. Bow
and Tilt
Tilt
Mal-aligned
Variation in SNNPR
for all Frequency Slots
at each Degradation
NPR db
70
60
50
40
30
20
10
15
20
25
Baseband Loading dbm0

Fig. IV - 5

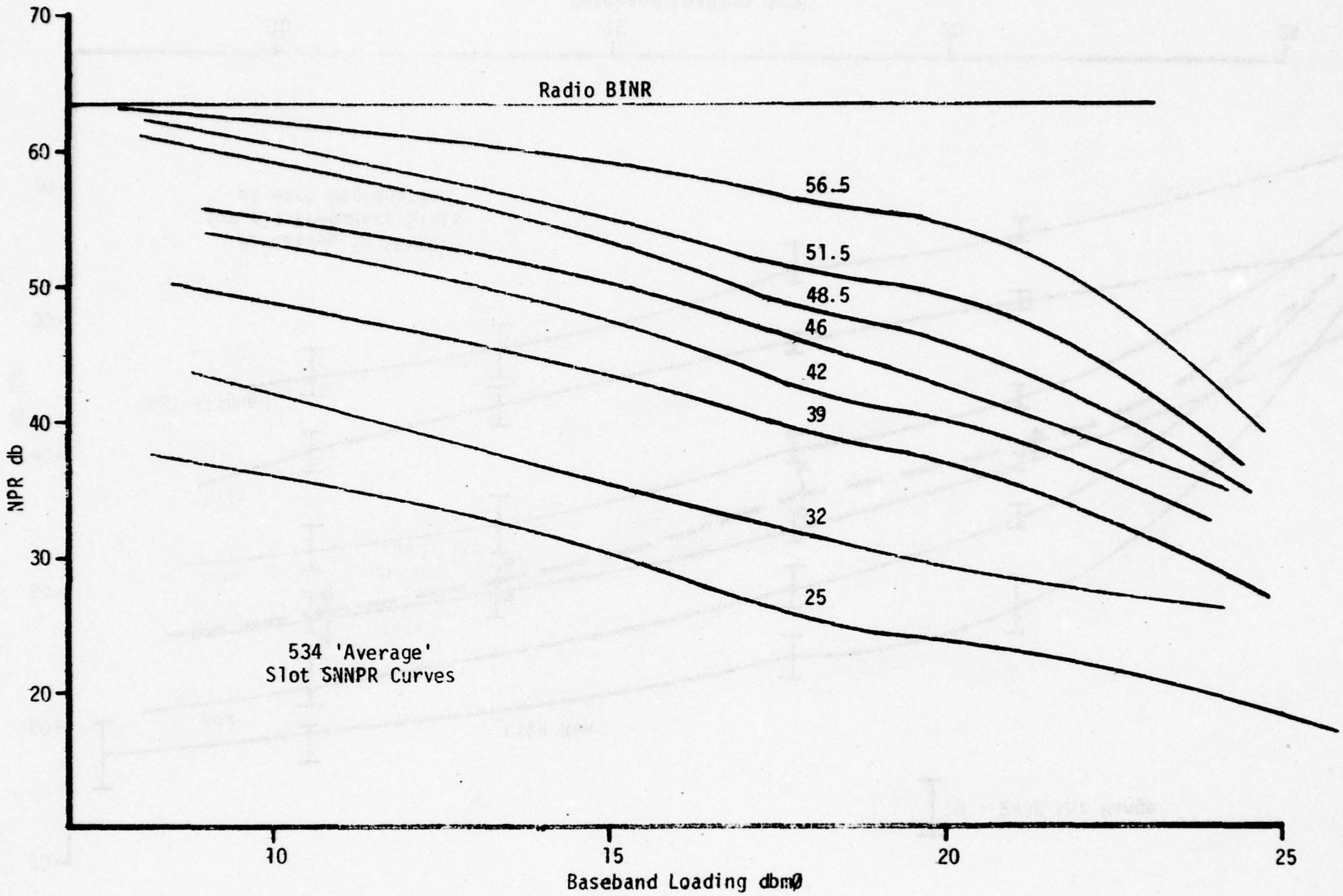

70
60
50
40
30
20
NPR db
Radio BINR
56.5
51.5
48.5
46
42
39
32
25
534 'Average'
Slot SNNPR Curves
10
15
20
25
Baseband Loading dbm0

Fig. IV - 6

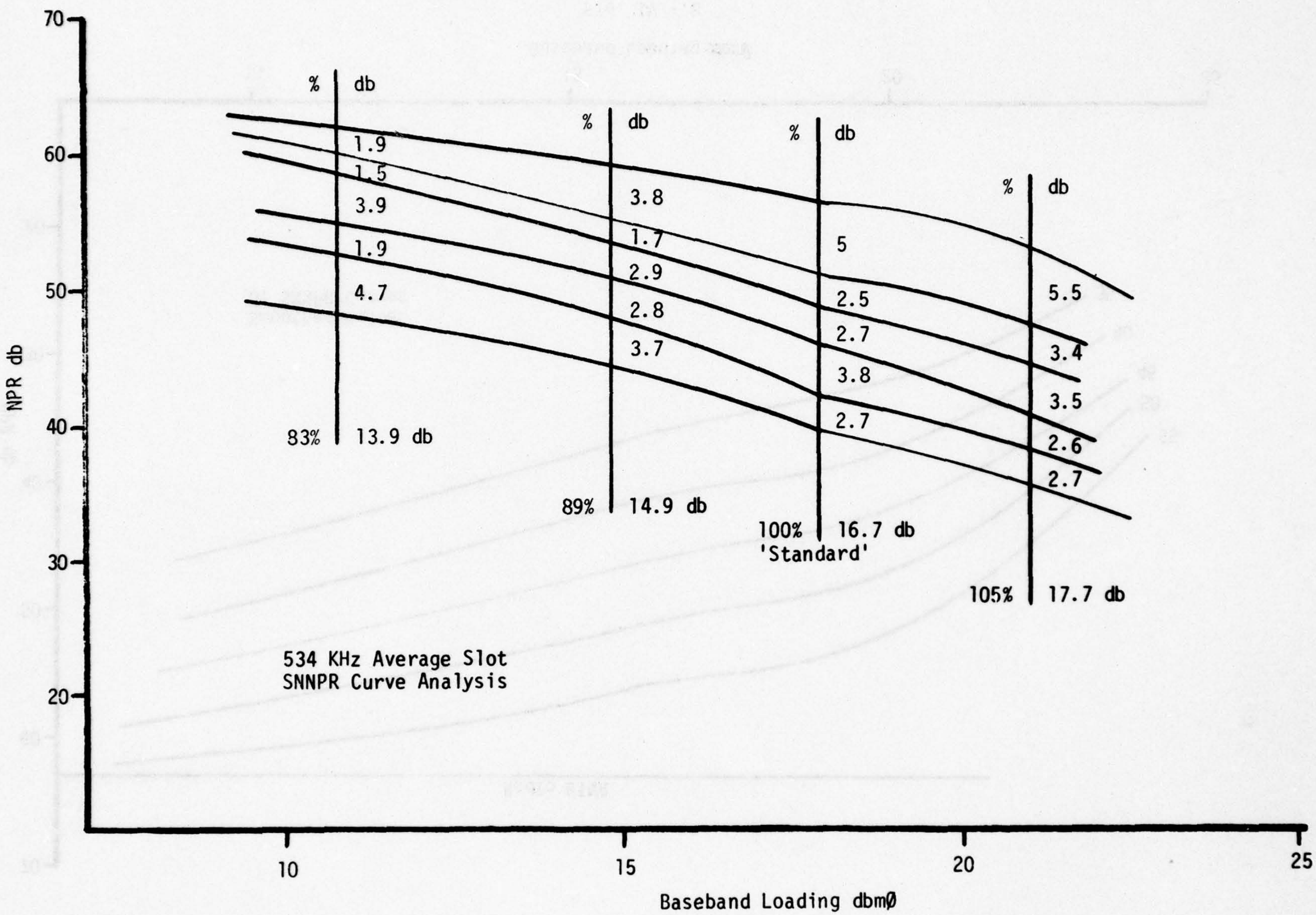

NPR db
70
60
50
40
30
20
10
15
20
25
Baseband Loading dbmØ
% db
1.9
1.5
3.9
1.9
4.7
83% 13.9 db
% db
3.8
1.7
2.9
2.8
3.7
89% 14.9 db
% db
5
2.5
2.7
3.8
2.7
100% 16.7 db
'Standard'
% db
5.5
3.4
3.5
2.6
2.7
105% 17.7 db
534 KHz Average Slot
SNNPR Curve Analysis

Fig. IV - 7

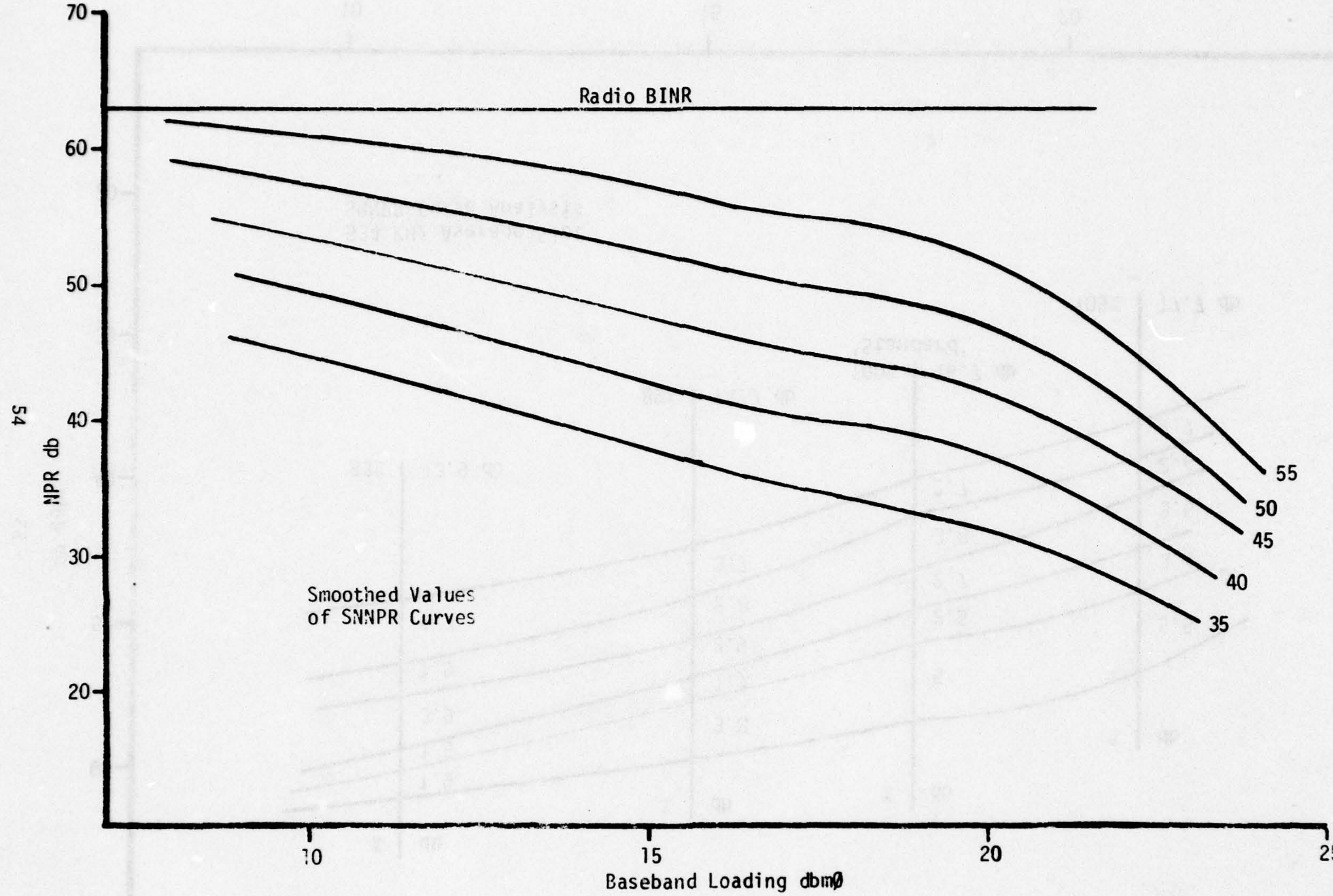

70
60
50
40
30
20
NPR db
Radio BINR
Smoothed Values
of SNNPR Curves
55
50
45
40
35
10
15
20
25
Baseband Loading dbmØ

Fig. IV - 8

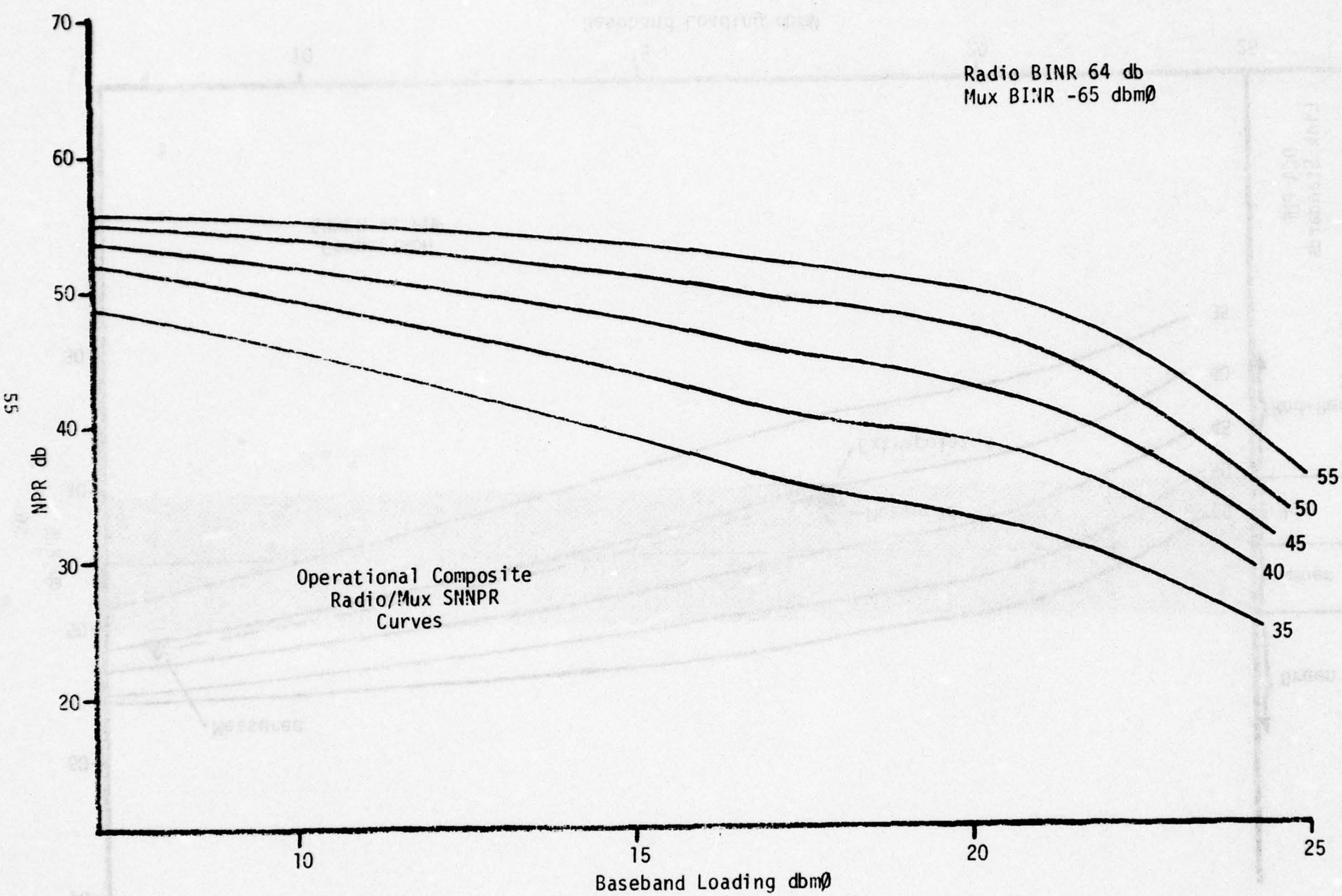

Radio BINR 64 db
Mux BINR -65 dbm∅
Operational Composite
Radio/Mux SNNPR
Curves
NPR db
70
60
50
40
30
20
10
15
20
25
55
50
45
40
35
Baseband Loading dbm∅

Fig. IV - 9

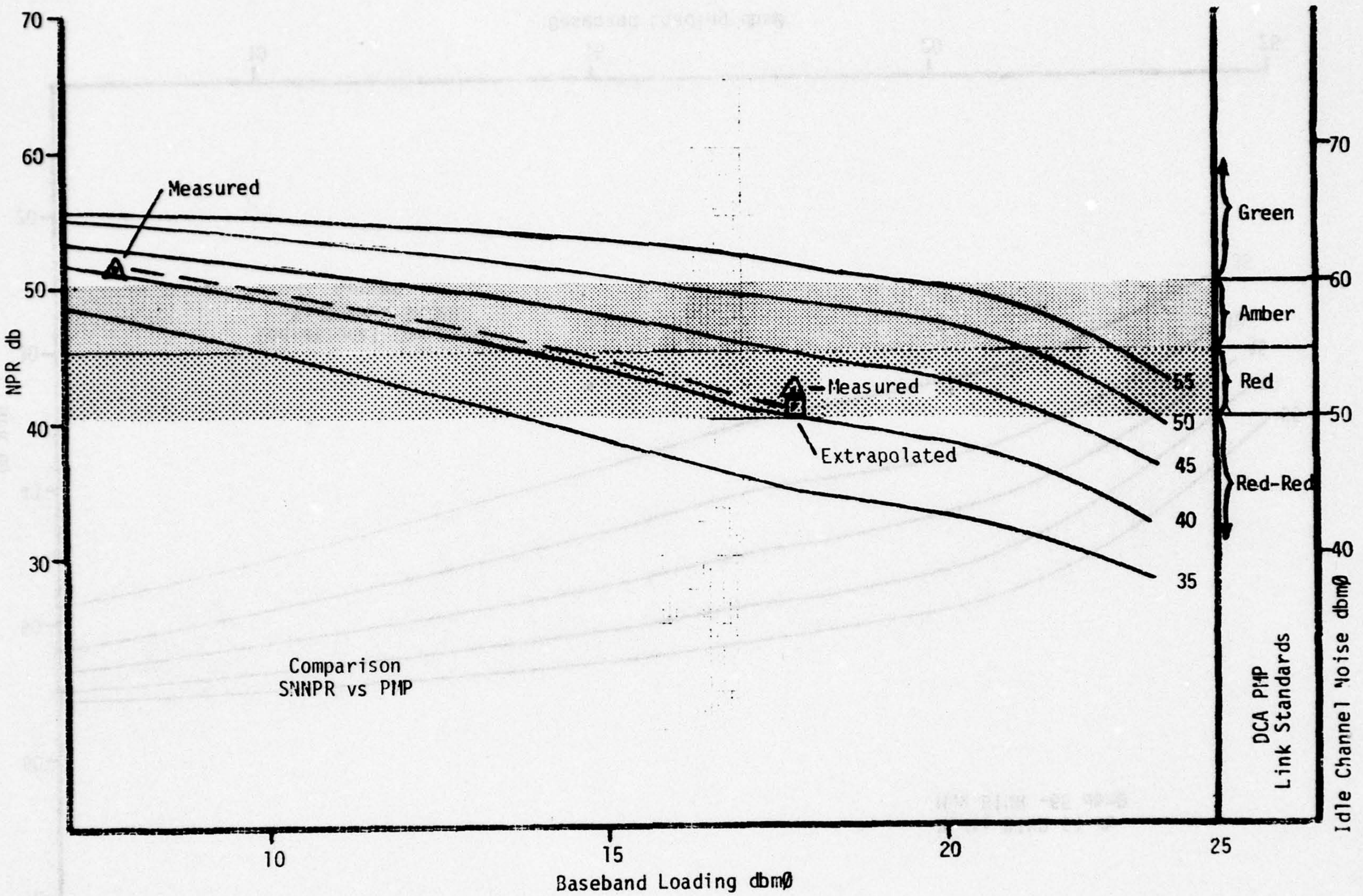

Measured
Measured
Extrapolated
Comparison
SNNPR vs PMP
NPR db
70
60
50
40
30
10
15
20
25
Baseband Loading dbm0
55
50
45
40
35
Green
Amber
Red
Red-Red
DCA PMP
Link Standards
Idle Channel Noise dbm0

Fig. IV - 10

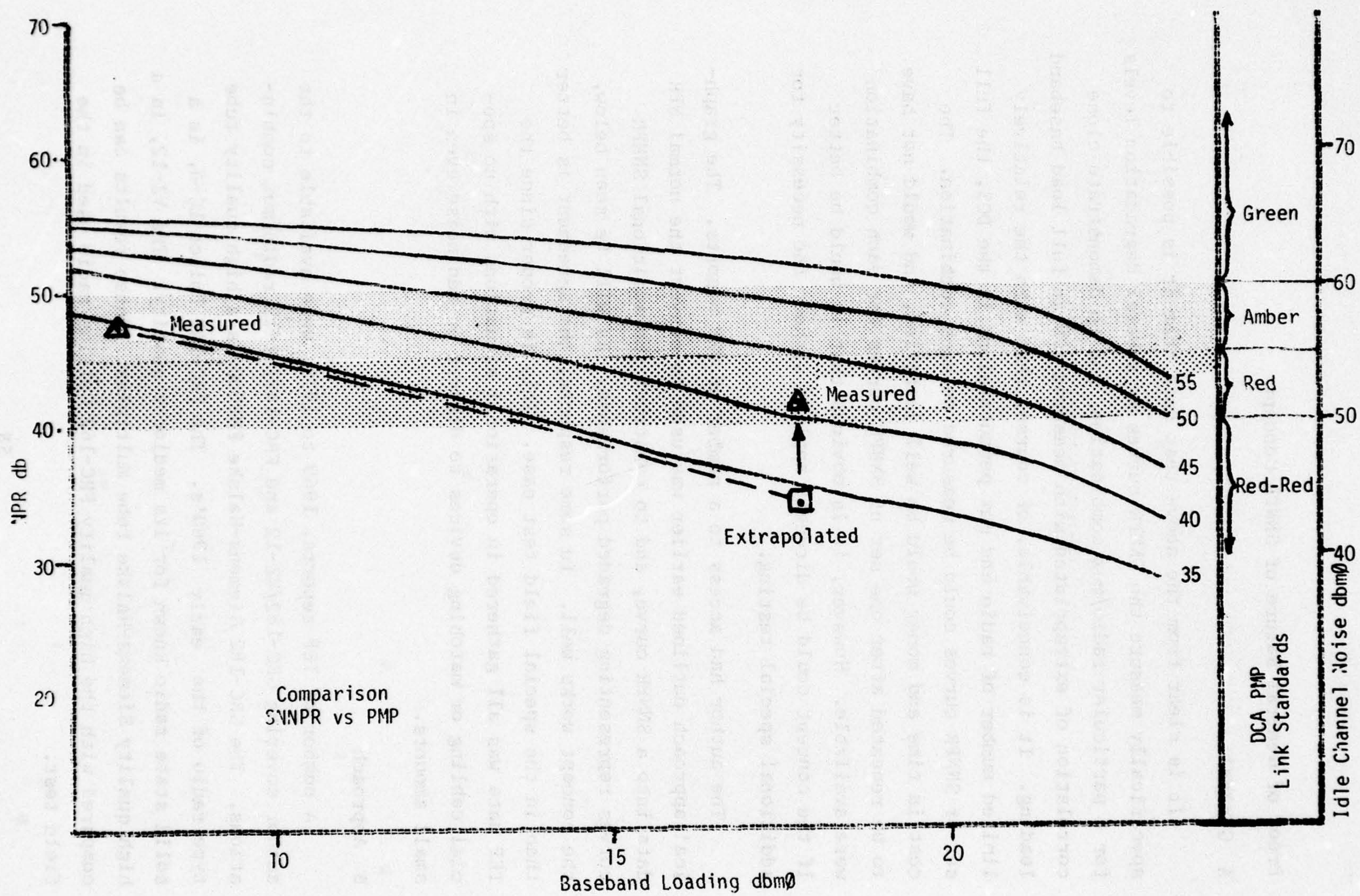

NPR db
70
60
50
40
30
20
Measured
Measured
Extrapolated
Comparison
SNNPR vs PMP
55
50
45
40
35
Green
Amber
Red
Red-Red
DCA PMP
Link Standards
70
60
50
40
Idle Channel Noise dbm0
10
15
20
Baseband Loading dbm0

Fig. IV - 11

V Proof of General Nature of SNNPR Concept

A General

It is clear from the above test data that it is possible to specifically measure the SNNPR curves at several degradation levels for a particular radio/mux combination, and to demonstrate close correlation of extrapolated with measured ICN at full load baseband loading. It is conceivable, of course, that with the relatively limited number of radio and mux permutatuions in the DCS, the full set of SNNPR curves could be measured on each combination. The cost in time and money would be well justified, and would not have to be repeated after one set of SNNPR curves for each combination were available. However, it is obvious that it would be better if the concept could be directly applied without the necessity for additional special testing.

The author had access to a number of TEP reports. The graphical approach outlined earlier was used to convert the normal NPR data into a SNNPR curve, and to construct the additional SNNPR curves representing degraded performance. As will be seen below, the concept works well. In some respects, the agreement is better than in the special field test case. This is proper since the TEP data was all gathered in operational situations with no special cabling or matching devices to distort or add noise even in small amounts.

B Approach

A number of TEP reports, 1969 to 1973, were available to the author covering GRC-182/VZ-12 and FRC-148/VZ-12 radio/mux combinations. The GRC-182 Siemens-Halske FM8000 is a high quality tube type radio of the early 1960's. The FRC-148 Philco LC-4, is a solid state radio known for its mediocre quality. The VZ-12, is a high quality Siemens-Halske tube multiplex. These results can be compared with the high quality FRC-162 Collins radio used in the field test.

1 Siemens-Halske Radio and Multiplex

The Siemens-Halske GRC-182/VZ-12 TEP data was examined first, and a proper NPR curve selected, that is with a smooth inverted 'U' shape and peaking at 55 NPR at the full baseband loading. Recall that the SNNPR curves must derive from a properly aligned radio NPR curve or correct degradation estimates from 'like new' will not be ascertained. Several good curves were available. The NPR curve for the mid slot was selected, since it is the 'average' curve.

The NPR data was replotted in the form of Figure V-1. Thus, the BINR data was recovered even though it was recorded only at full CCIR baseband loading. Once this data was available, the 55 SNNPR curve of Figure V-2, could be plotted. At full baseband loading of a proper GRC-182, the BINR was 64 db, and the SNNPR was 55 db. Similarly, at 0 dbmØ loading the NPR curve was 3.3 db noisier than the BINR (56.5 -53.2). Thus, SNNPR was plotted at 64 - 3.3 = 60.7 db. The balance of the 55 SNNPR curve was plotted similarly.

The next step was to construct the 35 through 50 db SNNPR curves. The logic displayed in Figure IV-7, was used to position the four additional curves. Figure V-2, portrays the final radio SNNPR curves.

The next step was to derive a mux BINR/IM curve. From work performed earlier for DCA and at AFCS, the shape of the mux noise curve was known and displayed in Figure III-17. This curve was rated full load at +17 dbmØ. This curve was one of several with differing full load values. They all had the same generic contour, with the value of the combined BINR and intermod noise at full baseband load 1½ to 2½ db noisier than the BINR. Thus, to use this curve at any loading, the curve was displaced laterally until the full load mux value was the same as the radio full baseband loading. The BINR value of the VZ-12 mux was plotted as -71 dbmØ. This is a 'like new' reasonable value, although some well maintained sets have BINR noise in excess of -71 dbmØ. Figure V-3, shows the mux noise curve.

The last step was to combine the radio SNNPR and mux curves, as explained earlier in this report - see Figure III-18. The resulting SNNPR curves as displayed in Figure V-4, represent the theoretically derived SNNPR curves for the Siemens-Halske GRC-182/VZ-12, derived from the standard NPR curve, with no special measurements required.

The basic question of course, was; does the derived curve bear accurate operational correlation to ICN values measured in operation use in the field?

Figure V-5, shows eight TEP operational link measurements plotted on the SNNPR curves. The vertical line represents the spread of four (or six) values of link NPR's measured during the TEP. There are routinely four NPR values measured resulting from combinations of local receivers A&B, and remote transmitters A&B. In some cases, two additional values are determined - that of remote transmitters A&B with combined Receivers A+B. The small triangle represents the actual idle channel noise measured over the link. It must be noted that all NPR tests are conducted at full baseband loading, thus all of these vertical lines should be plotted at full CCIR baseband loading. The triangles are plotted at the actual measured baseband loading. For visualization simplicity, the NPR values were plotted with the associated ICN triangle, with the NPR extent carefully preserved. In few cases, it is possible to ascertain which transmitter and receiver were in operational use when the ICN readings were taken, so precise correlation with a single NPR value was not possible. This hardware identification should be specified in future TEP efforts so that precise results can be obtained - and to prove TEP data correlation as described in the Technical Evaluation Program Analysis Procedures report.

Thus, the correlation is accomplished if the ICN's fall within the range of measured NPR values. Figure V-5, portrays the operational TEP results. All operational results check well - with one exception. In that one exception, the TEP report specifically highlighted the very noisy mux. The mux ICN was measured during the link outage to be high in the back-to-back mode. The noise showed on the SNNPR plot as apparent excessive NPR degradation.

Clearly, the Siemens-Halske radio/mux SNNPR curves prove reasonable technical correlation and operational suitability. This is not restricted to relatively well aligned links. One of the plots (Bann, NPR 46) was the pre-TEP assessment taken in the early TEP phases and prior to any alignment or adjustment. It is interesting to note that in this example where the operational loading was full load, the ICN gain was 5 db due to TEP. Had the load been 7 to 10 db light, the ICN gain would have been 1 db or less. No wonder that many mangement personnel fail to recognize the value of a proper TEP effort. The SNNPR concept can ameliorate this management problem.

2 Philco Radio and Siemens-Halske Multiplex

The Philco FRC-148/VZ-12, TEP data was examined next, and a suitable NPR curve derived. Since none of the ten NPR curves had the proper maximum of 55 db and the appropriate slope above and below the full load point, the resulting NPR curve was an average of the reasonably close curves. See Figure V-6. Figures V-7, V-8, and V-9, show the interim steps to construct the final SNNPR curves as displayed in Figure V-10.

Figure V-11, displays the operational correlation data for ten links as extracted from TEP reports. The four or six NPR value lines and the small triangle to denote the idle channel noise over the link, were portrayed as in the previous section. Again, all values correlate very well except one. Langerkopf mux ICN measured very high back-to-back during the TEP link outage, and this noise swamped the link normal performance - the basic noise in the mux caused excessive apparent NPR degradation.

Obviously this second radio/mux combination proved reasonable technical correlation and operational suitability. This operational usefulness again was not restricted to well aligned links, since six of the post TEP performance levels were below 50 db and one as low as 41 db NPR.

C Operational Summary

As discussed above, correlation was proved in all cases where the triangle plotted somewhere on the NPR value line. This is not completely soul satisfying in those cases where the NPR line extends from 41 to 54 db as in the Philco LC-4 Langerkopf example. The ICN correlated with the poorest 41 db value. However, among the other link cases, there were several where the variation among the measured NPR's was only 2 or 3 db. Correlation in these instances clearly proves technical and operational suitability. It does not matter whether the NPR values are good or bad - the key issue is coincident plotting. At least nine of the eighteen specific lin'. examples prove correlation certainly to less than 2 db, although a more precise figure might be justified. Such correlation was proved over baseband loading values of 10 db below to 4 db above full load conditions.

The remaining nine examples may be within 1 or 2 db, but such accuracy cannot be proved by the divergent TEP NPR data.

Reference to the 'T.E.P. Analysis Procedures' report prepared by the author for DCA, discloses that the empirically derived SNNPR curves were useful to prove (or more often disprove) TEP measurement correlation. The SNNPR concept permitted correction of errors and generally proved more precise than the TEP measurements themselves. Consequently, the thought arises as to the necessity of the TEP, if the SNNPR approach were adopted. Quite obviously a SNNPR program would surface most link problems, and the TEP effort could be reduced. Intermittent difficulties, problems with conditioning equipment or network hardware would not be detected. A TEP program still would be required, but could be resized, retimed, and generally used in other than a rote periodic link assessment.

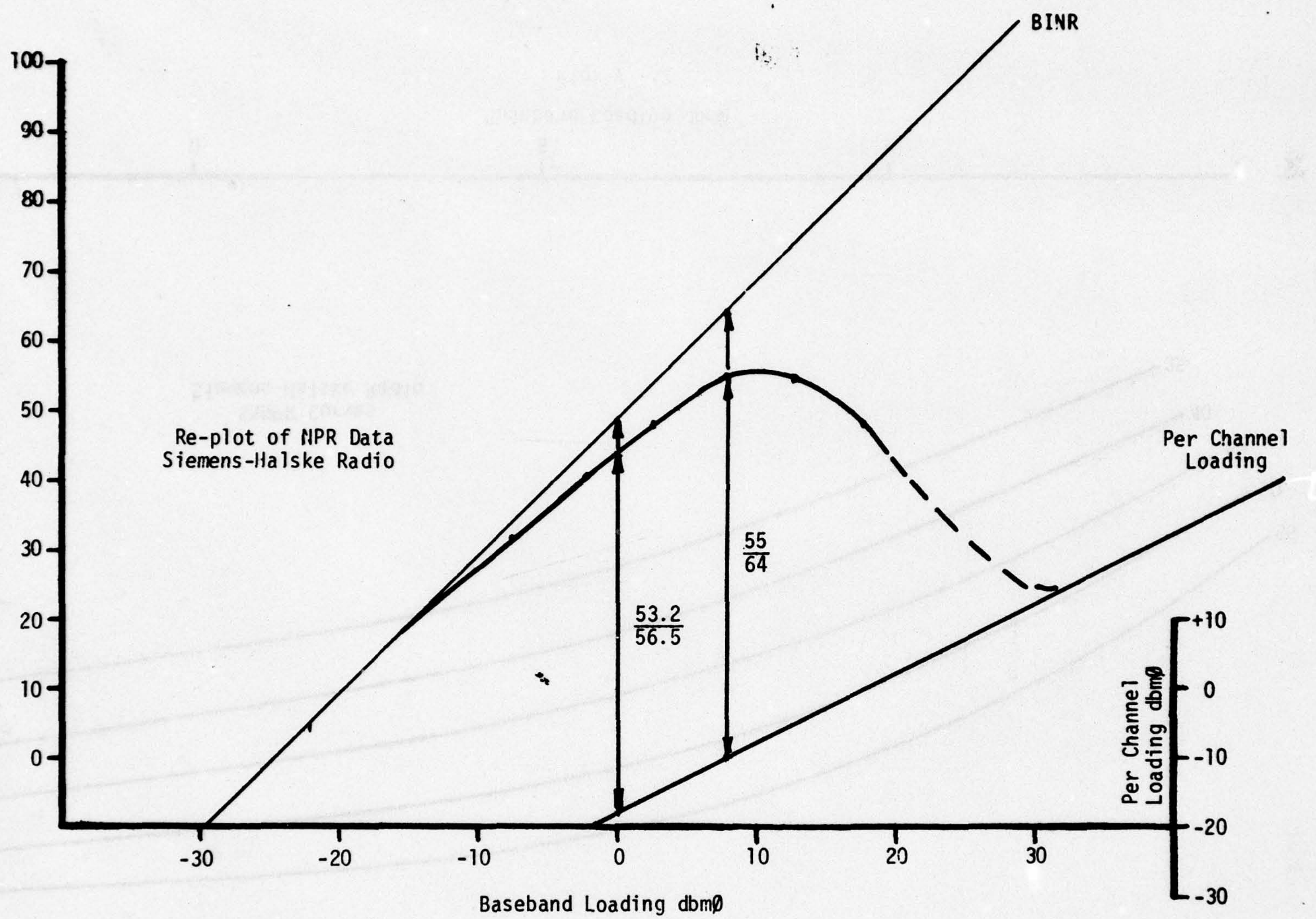

BINR
Re-plot of NPR Data
Siemens-Halske Radio
db
100
90
80
70
60
50
40
30
20
10
0
-30
-20
-10
0
10
20
30
Baseband Loading dbmØ
53.2
56.5
55
64
Per Channel
Loading
Per Channel
Loading dbmØ
+10
0
-10
-20
-30

Fig. V - 1

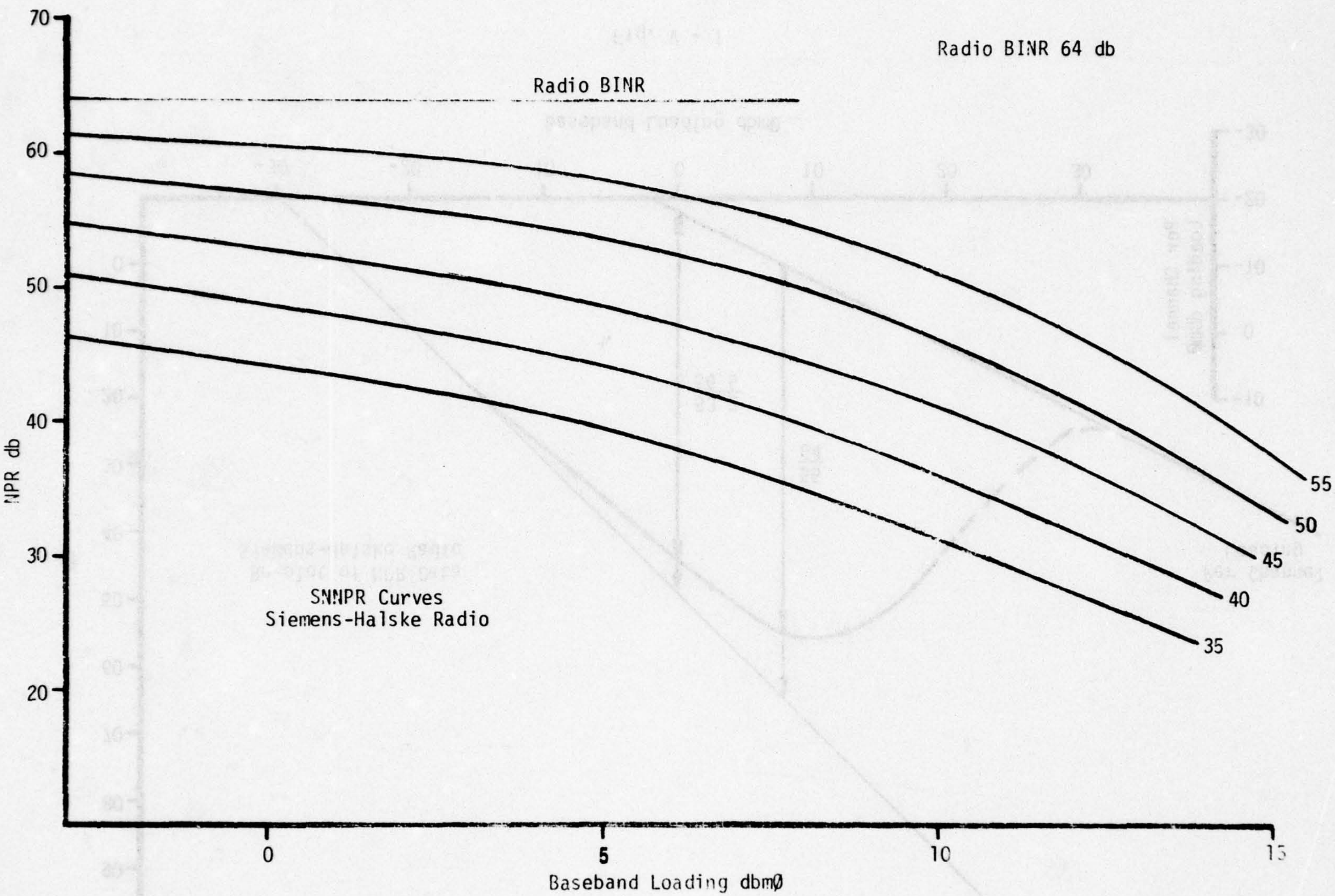

Radio BINR 64 db
Radio BINR
SNNPR Curves
Siemens-Halske Radio
NPR db
70
60
50
40
30
20
0
5
10
15
55
50
45
40
35
Baseband Loading dbmØ

Fig. V - 2

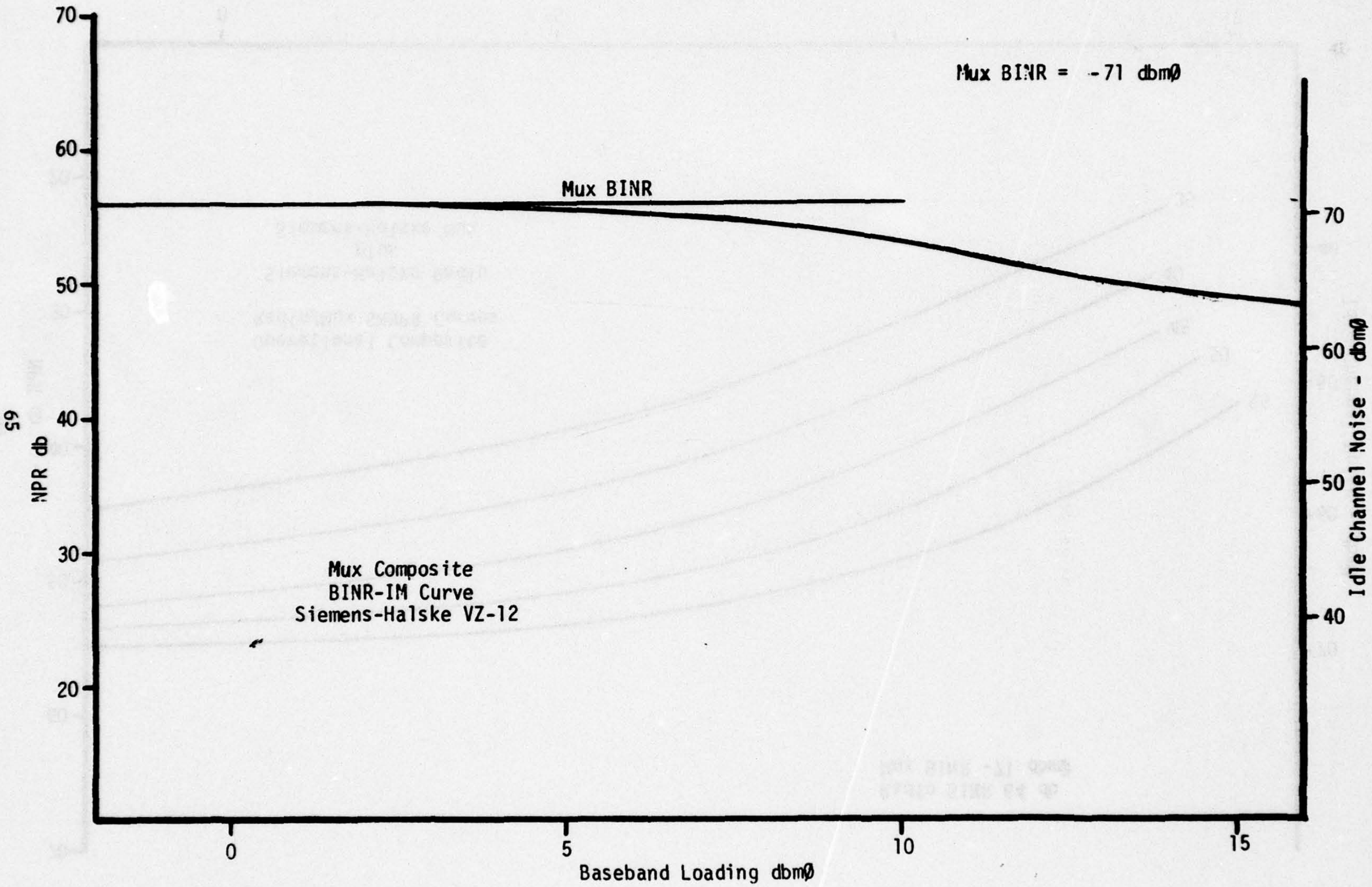

Mux BINR = -71 dbmØ
Mux BINR
Mux Composite
BINR-IM Curve
Siemens-Halske VZ-12
NPR db
70
60
50
40
30
20
Idle Channel Noise - dbmØ
70
60
50
40
0
5
10
15
Baseband Loading dbmØ

Fig. V - 3

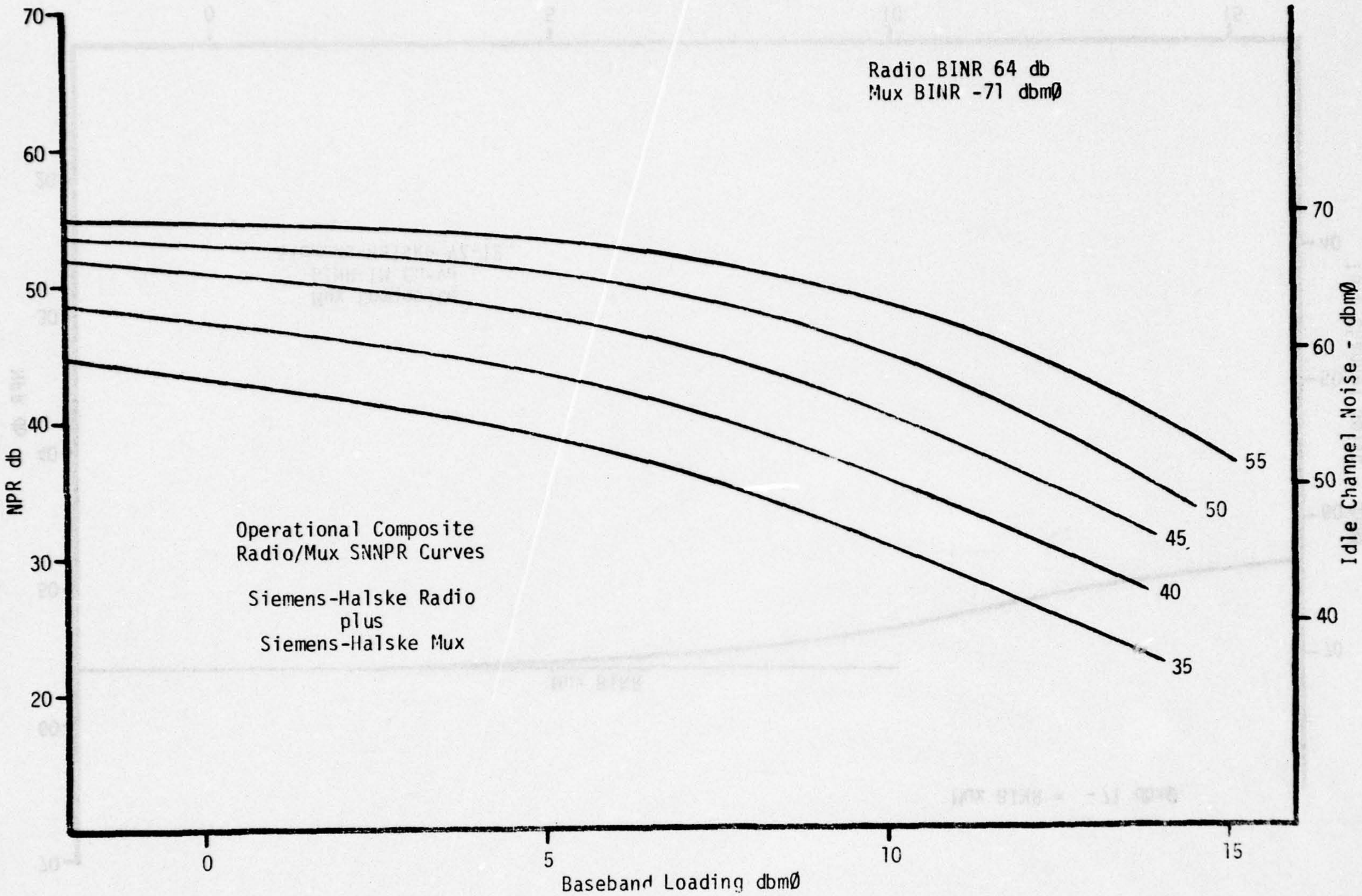

Radio BINR 64 db
Mux BINR -71 dbmØ
Operational Composite
Radio/Mux SNNPR Curves
Siemens-Halske Radio
plus
Siemens-Halske Mux
NPR db
70
60
50
40
30
20
Idle Channel Noise - dbmØ
70
60
50
40
55
50
45
40
35
0
5
10
15
Baseband Loading dbmØ

Fig. V - 4

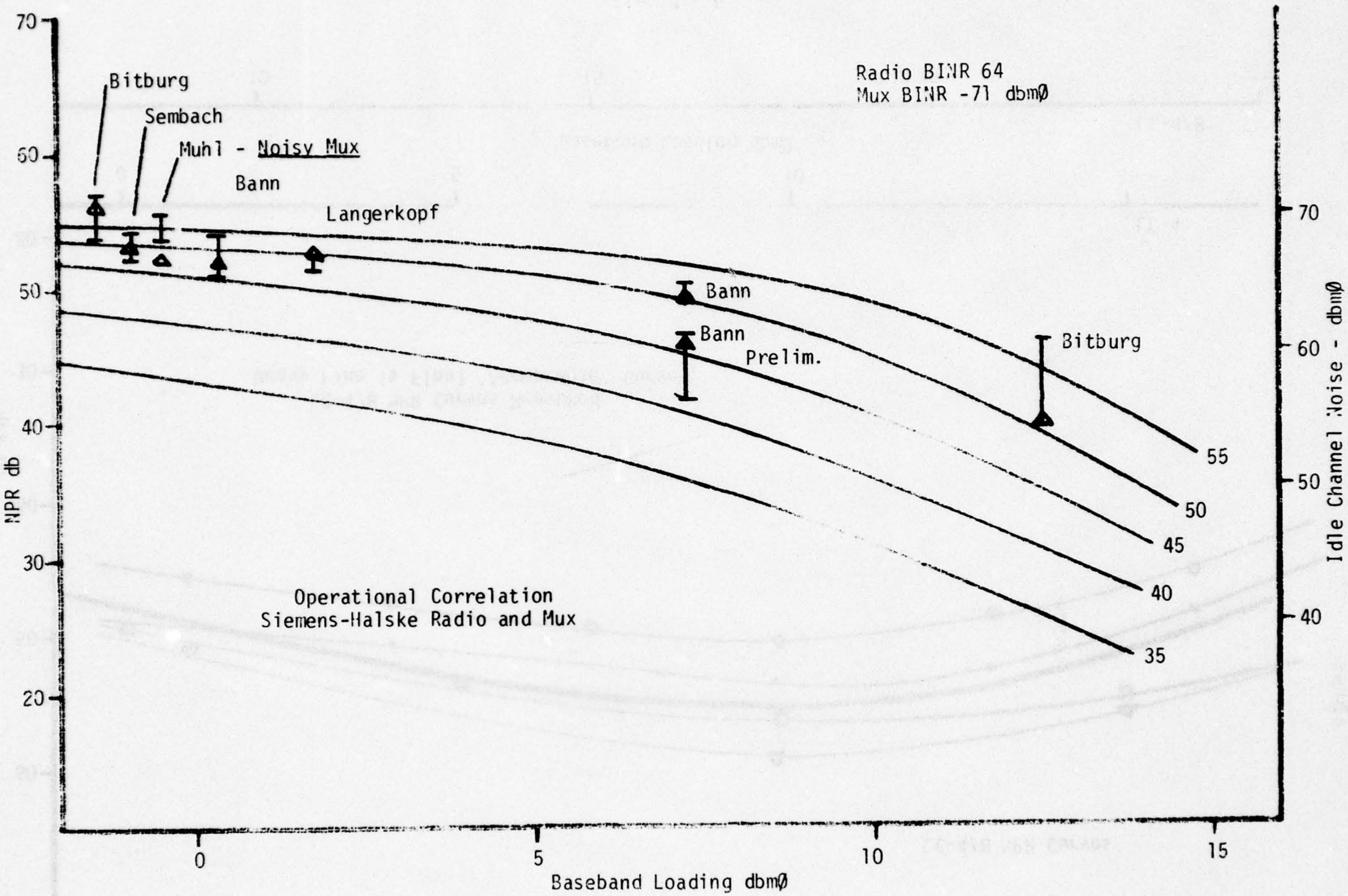

Radio BINR 64
Mux BINR -71 dbmØ
Bitburg
Sembach
Muhl - Noisy Mux
Bann
Langerkopf
Bann
Bann
Prelim.
Bitburg
Operational Correlation
Siemens-Halske Radio and Mux
55
50
45
40
35
NPR db
Idle Channel Noise - dbmØ
Baseband Loading dbmØ

Fig. V - 5

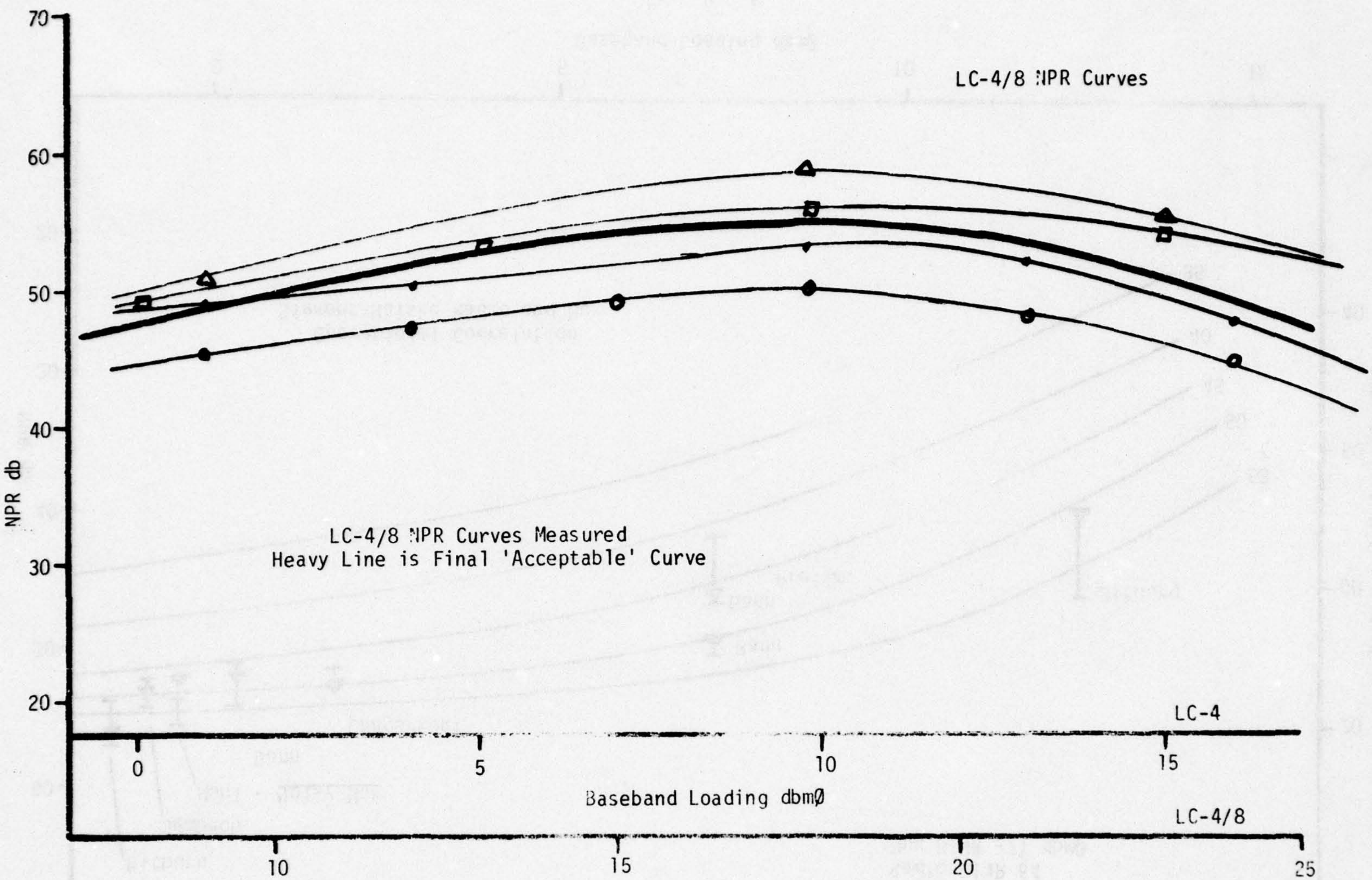

LC-4/8 NPR Curves
70
60
50
40
30
20
NPR db
LC-4/8 NPR Curves Measured
Heavy Line is Final 'Acceptable' Curve
LC-4
0
5
10
15
Baseband Loading dbmØ
LC-4/8
10
15
20
25

Fig. V - 6

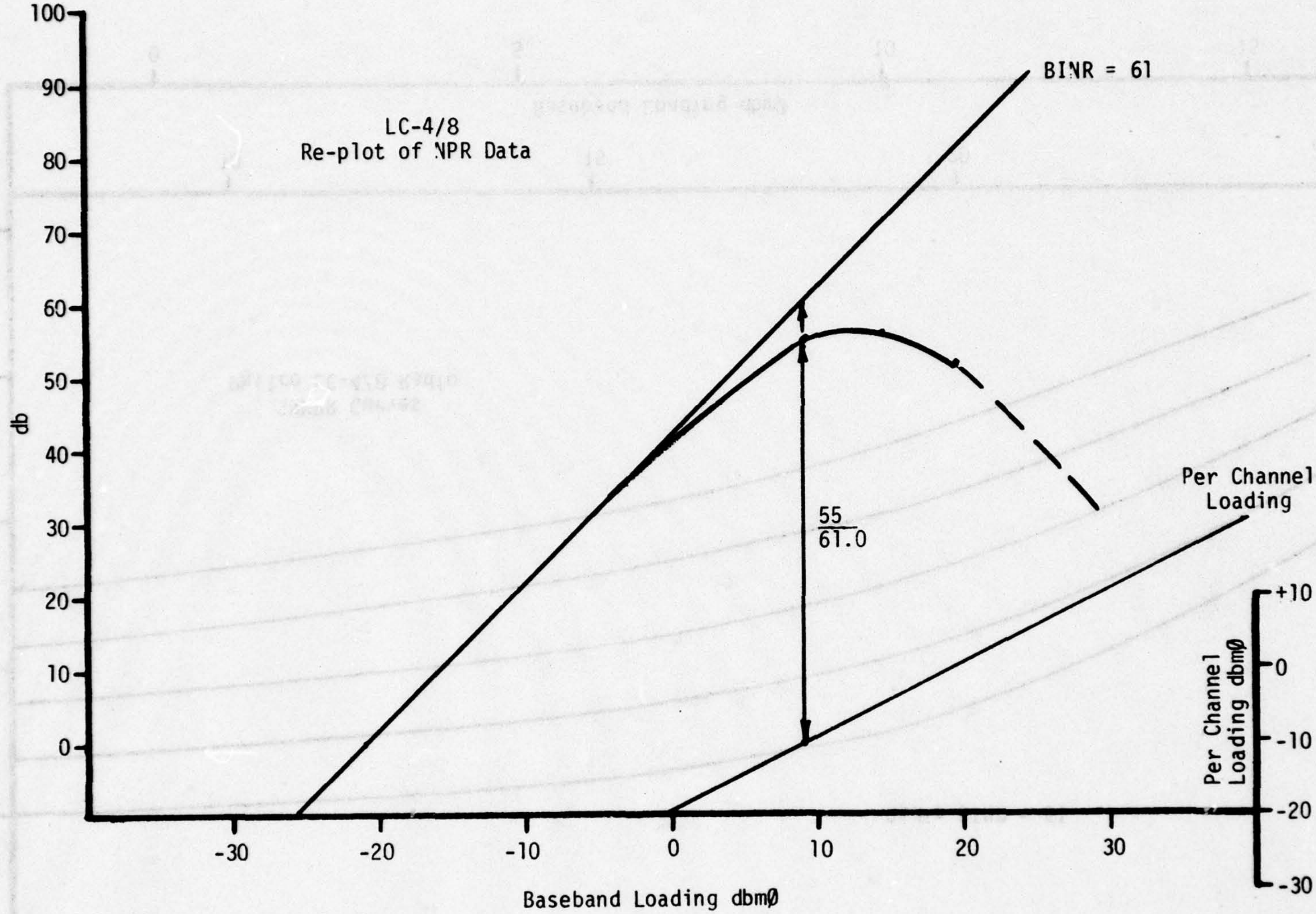

LC-4/8
Re-plot of NPR Data
BINR = 61
55
61.0
Per Channel
Loading
db
100
90
80
70
60
50
40
30
20
10
0
-30
-20
-10
0
10
20
30
Baseband Loading dbmØ
+10
0
-10
-20
-30
Per Channel
Loading dbmØ

Fig. V - 7

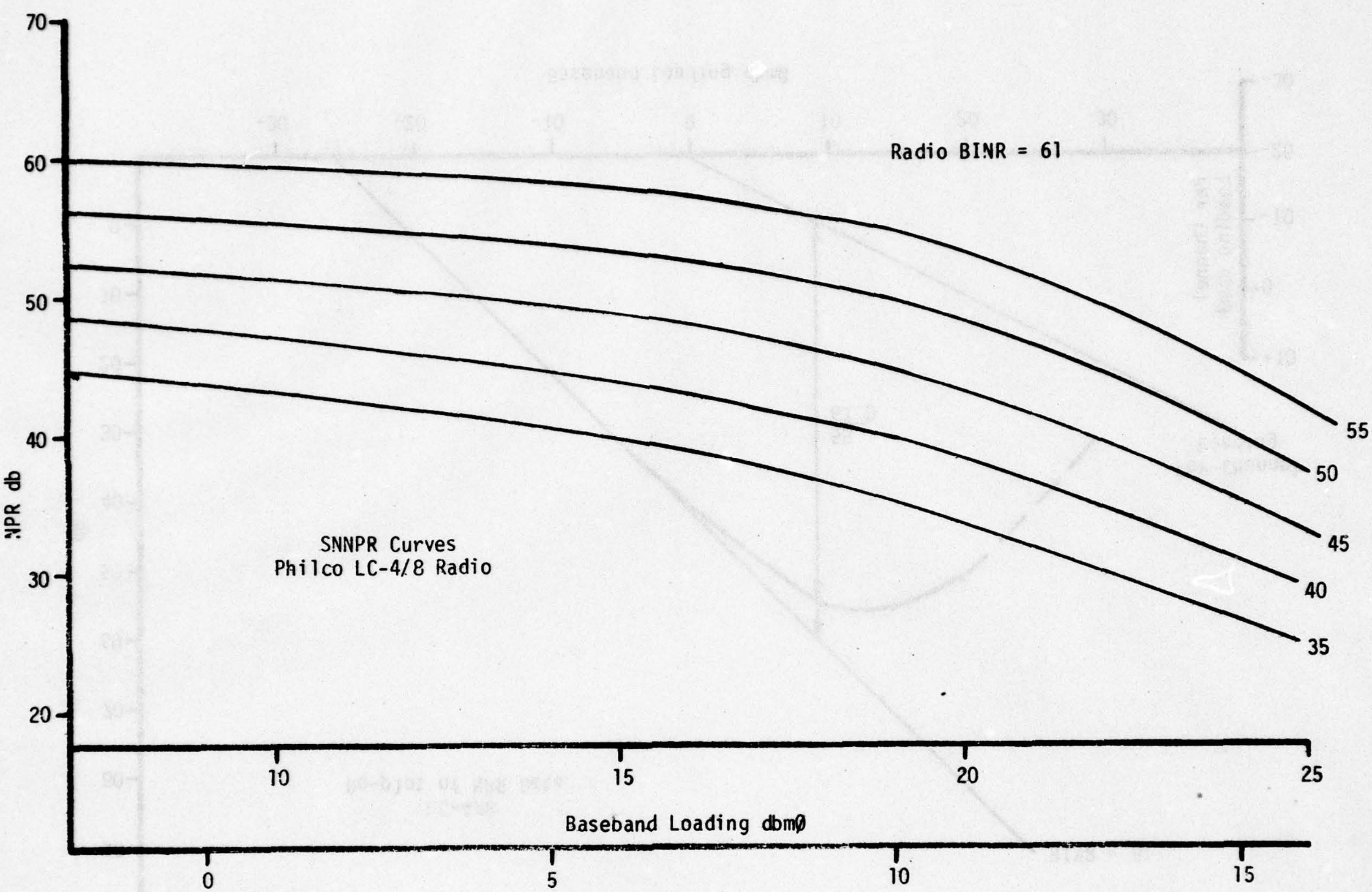

Radio BINR = 61
SNNPR Curves
Philco LC-4/8 Radio
NPR db
Baseband Loading dbm0
70
60
50
40
30
20
10
15
20
25
0
5
10
15
55
50
45
40
35

Fig. V - 8

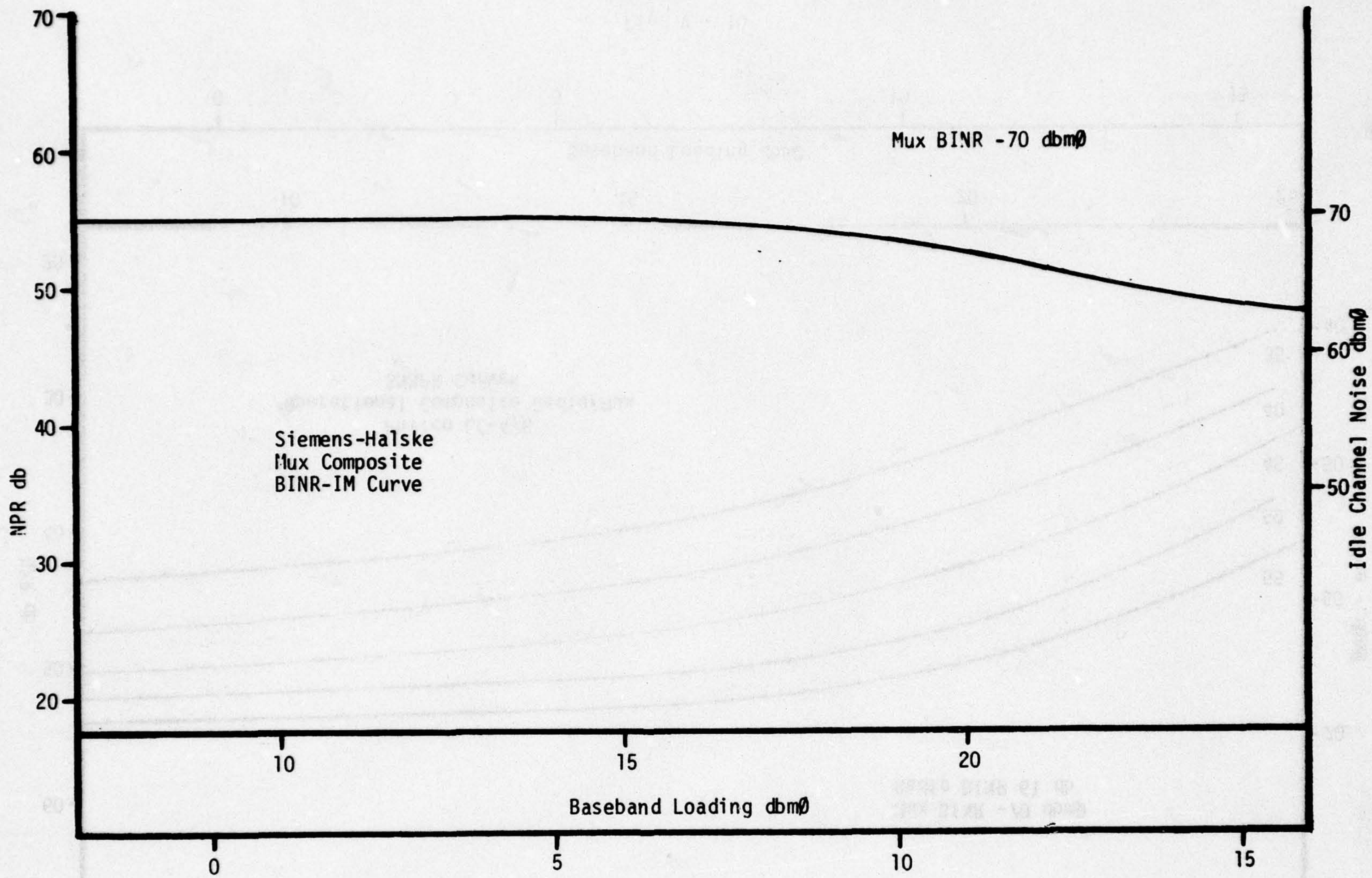

Mux BINR -70 dbmØ
Siemens-Halske
Mux Composite
BINR-IM Curve
NPR db
70
60
50
40
30
20
Idle Channel Noise dbmØ
70
60
50
Baseband Loading dbmØ
10
15
20
0
5
10
15

Fig. V - 9

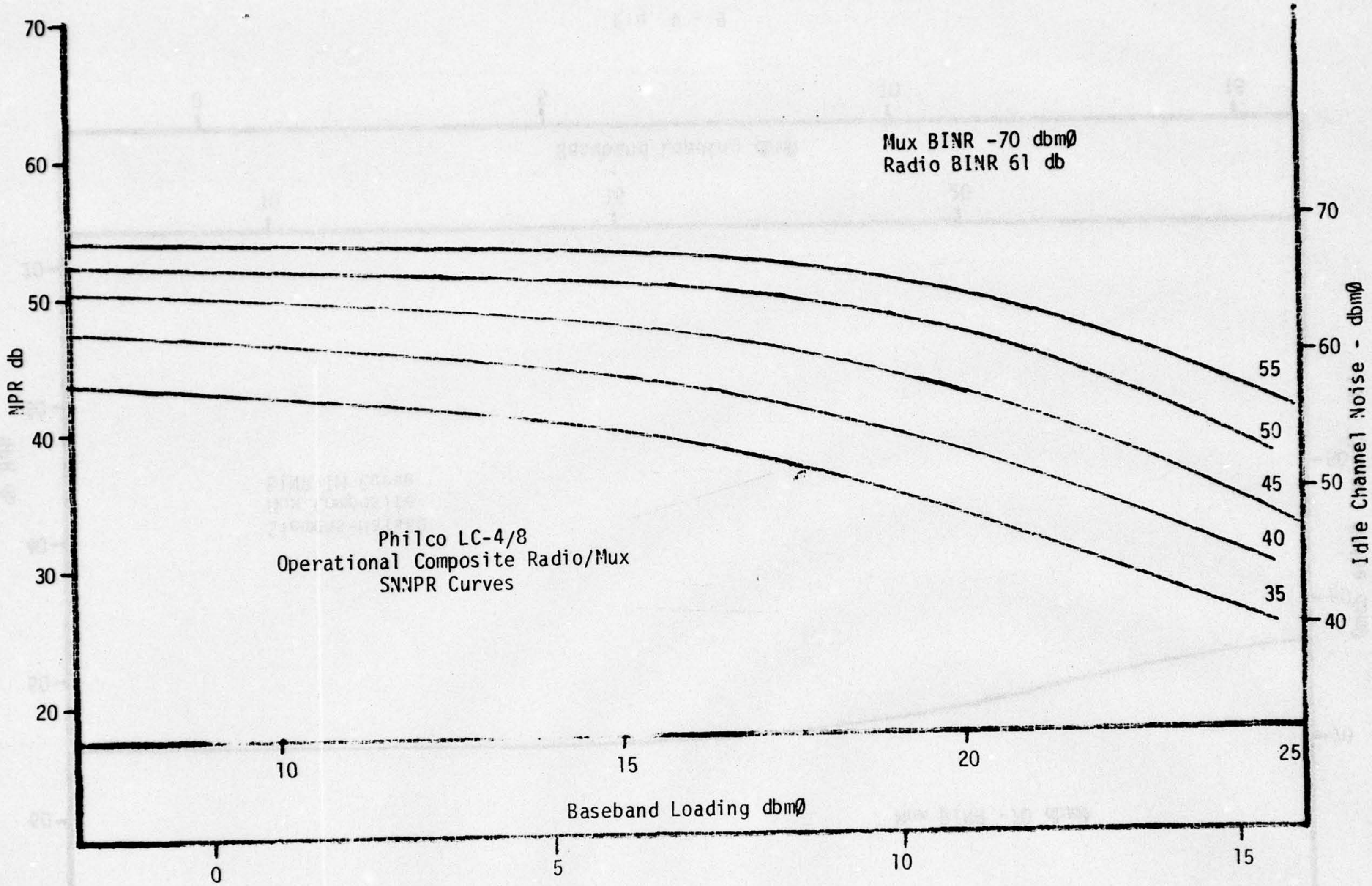

Mux BINR -70 dbmØ
Radio BINR 61 db
Philco LC-4/8
Operational Composite Radio/Mux
SNNPR Curves
NPR db
70
60
50
40
30
20
Idle Channel Noise - dbmØ
70
60
50
40
55
50
45
40
35
10
15
20
25
Baseband Loading dbmØ
0
5
10
15

Fig. V - 10

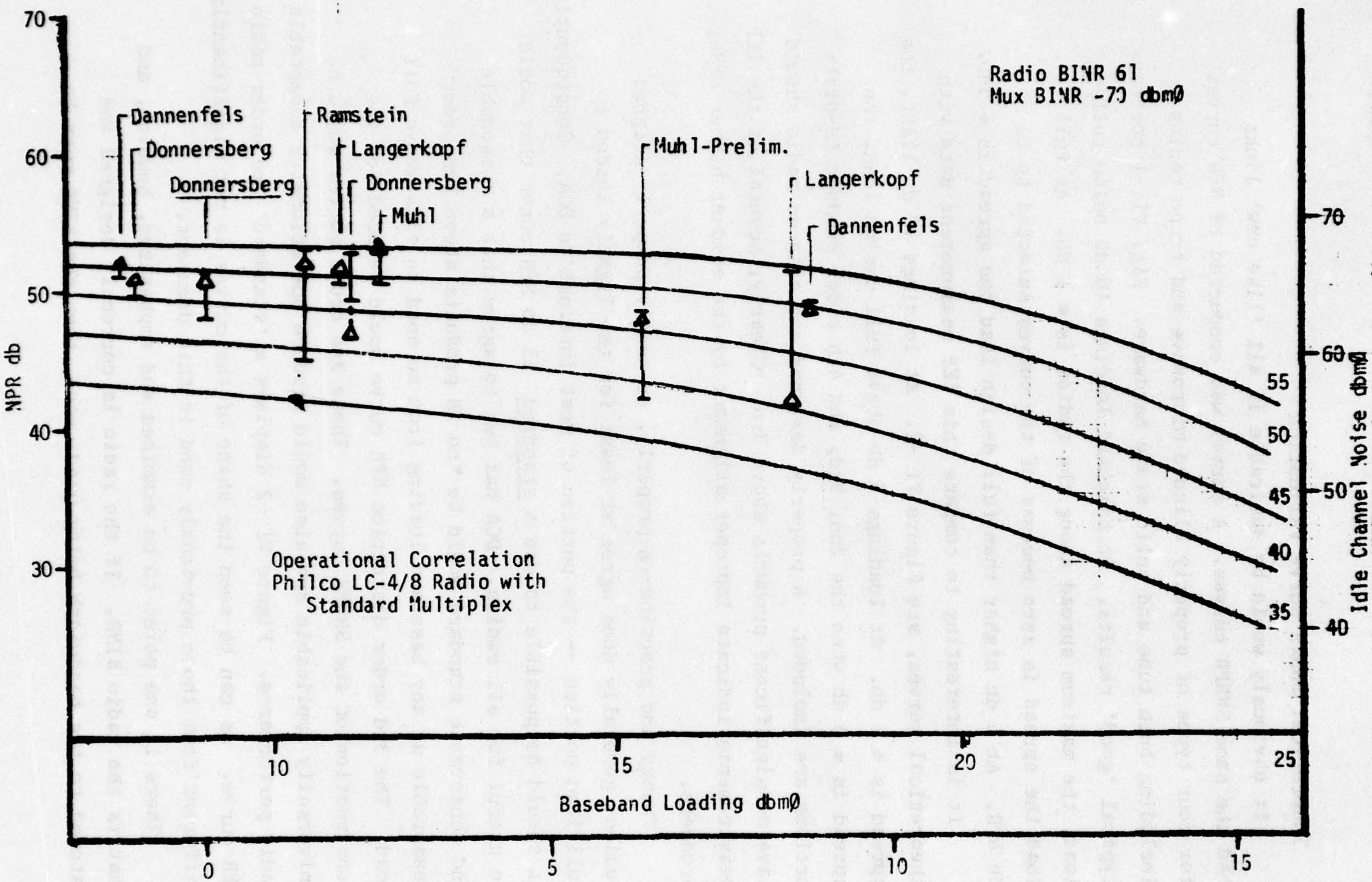

Radio BINR 61
Mux BINR -70 dbm0
Dannenfels
Donnersberg
Donnersberg
Ramstein
Langerkopf
Donnersberg
Muhl
Muhl-Prelim.
Langerkopf
Dannenfels
Operational Correlation
Philco LC-4/8 Radio with
Standard Multiplex
NPR db
Baseband Loading dbm0
Idle Channel Noise dbm0
70
60
50
40
30
55
50
45
40
35
10
15
20
25
0
5
10
15

Fig. V - 11

VI Theoretical SNNPR Curve Validation

It obviously would be desirable if all 'like new' links had the same SNNPR curves. A survey was conducted of NPR curves for four types of properly aligned microwave and tropo radios including both tube and solid state hardware. Fig. VI -1 portrays typical 'good' results. At baseband loadings 10 db below full load, the maximum spread among the radios is ± 1 db. At full load the spread is zero because of the curves selected to be 55 db NPR. At 5 db higher than full design load the spread is ± 5db.

It is interesting to compare this TEP measurement data with theoretical curves, see Figure VI -2. At loadings 10 db light, the spread is ± 1 db. At loadings 5 db above full design load, the spread is ± 4 db when the 2nd, 3rd, and 4th order product IM distortions are included. A properly designed and aligned radio should have no significant products above 3rd. Clearly, several of the TEP measurements indicate improper alignment by the evident higher order products.

Theory and practice-on properly, or nearly properly aligned radios- generally does agree at least for the lightly loaded to full load portion -- the portion of most interest to DCA. Consequently, it should be possible to use a standard 55 db NPR curve that would be useful for all radios. DCA has but to agree that a reasonable and achievable standard would be "no IM products above 3rd order" measurable at any baseband loading from no noad to +3db above full load. The 3rd order distortion NPR curve would be used for the construction of the SNNPR curves. These 3rd order curves would be universally applicable and also would produce operationally acceptable radio performance. Figure VI -2 displays a 'standard' 3rd order radio NPR curve. As can be seen the shape of the curves is not significantly different from those previously used in this document.

There is one point to be examined and emphasized, however, and that is the radio BINR. If the radio is correctly designed and matched to the bandwidth being used, etc., then **the BINR must be**

3 db quieter than the NPR at full baseband loading. An NPR of 55 db requires a BINR of 58 db. (The BINR is 58, the intermodulation is 58 db, and the combined BINR + IM produces an NPR of 55 db)

The standard NPR in the DCS, as extracted from the tech order data, is routinely stated as 55 db. Most people accept this performance criteria as a maximum without question. In fact, it is a factory minimum performance lever only! The tech order fails to specify the BINR value. TEP report examination disclosed <u>no</u> well maintained radios in general use in the DCS that did not have BINR measured values in the 60s, and this included both tropo and microwave hardware. The significance of the 60+ db BINRvalue is evident when the generation of the NPR curve is recalled. The NPR curve maximum value occurs where the idle noise and the intermodulation noise are equal. Thus the NPR must be 3 db less than the idle noise value at full load. Since <u>all</u> radios, when properly maintained, have BINR values in the 60s, the proper NPR must be 57 db or better. Some of the later solid state equipment achieve a BINR of 64 to 65 db. The associated NPR then must be 61 to 62 db. There facts were demonstrated during this Collins FRC-162 test.

Figure VI -3 shows the Collins FRC-162 'normal' alignment from Figure II-6, and the 'premium' alignment from Figure II-8 plotted on one graph. It is clear that the BINR is fixed regardless of the alignment condition, and is a radio design matter. Any deterioration in BINR is related to noise from degrading components--normally bad capacitors, or induced noise currents from poor cabling. Since the NPR must peak 3 db noiser than the BINR-IM intersection, the best possible NPR must be 61.8 db. The 'premium' alignment achieved was 60.2 db and was within 1.6 db of maximum achievable.

This discussion is not to extol the excellence of the test alignment. Rather, it is to show that if NPR values of 55 db are assumed, then the BINR should be 58 db. If BINR values are accepted as actually measured in the field at 60 to 65 db, then the 'like new' NPR must be 57 to 62 db. The tech orders, the field maintainers, and the TEP teams, however, have been trained to regard 55 db NPR as perfect and to strive no further after this goal has been achieved. Actually little operational gain is observed directly by NPR values above 55 db, although the stability of the adjustments is significantly improved and time between adjustments is greatly extended by such 'premium care alignment.

All of this discussion may be technically interesting, but it is of very practical import. The shape of the NPR curves in Fig.VI -4 for NPR values of 61 and 62 is not much different, and are displaced from each other by about 1 db. This difference would not be operationally significant. The curves at NPR values of 60 and 55 db with a BINR of 64 db, however, is very different. The 60 and 55 db curves are 3 to 5 db displaced over the DCS baseband loading range of values.

In order to arrive at a 'standard' like new set of curves, not only an average BINR, but also an average NPR value must be selected. Recounting, NPR/BINR numbers of 55/58 are reasonable from an NPR standpoint, 61/64 are reasonable from a BINR viewpoint. The selection of a 55/64 pair is troublesome to plot and use accurately. The author had accepted a value for BINR nearly always met or exceeded in the field of 61 db. For operational reasons, and bowing to technical convention and habit, an NPR value of 55 db was selected. Thus there is some accommodation of a true 'like new' 'standard' radio curve to match 55 db with 61 db, but the deviations are reasonable. These variations from theory are acceptable, and the 1 to 2 db difference is nearly obscured by the BINR noise of the mux when the radio and mux curves are combined to produce the link curve. Thus the practical impact of the compromise 55/61 db operational radio SNNPR curve is ½ db or less uncertainty.

Figures VI -5 and 6 complete the radio SNNPR curve construction. The multiplex IM curve is portrayed in Fig. VI -7. The Mux BINR is a very important parameter, but is rarely, if ever, stated. A survey of a number of TEP reports discloses that at light baseband loadings, link idle channel noise readings of -70 dbmØ or quieter are acheived. (-71.5 dbmCØ) on at least a few of every mux type examined. Thus,

-70 dbmØ would be achievable for a 'like new' standard. Another approach to deciding the mux BINR standard starts from the loaded noise numbers that are available. One (and only one) manufacturer states that the full load per channel idle noise of his mux is 200 pwp. (-65.5dbmØ), and that the mux BINR is at least 3 db quieter. (-68.5 dbmØ) Splitting the difference would give a figure of -69.25 dbmØ or -69 dbmØ. This is the BINR used to construct the 'standard' link SNNPR.

The final theoretical standard link SNNPR curve is portrayed in Figure VI -8. There is a point of importance portrayed in Figures VI -8 and 9. At light loading, the Figure VII-8 DCA loading SNNPR curves are spread more but have slightly noiser idle channel noise at light loading than the Figure VI -9 CCIR loading curves. This is because the DCA -10 dbmØ per channel loading causes the multiplex curve to be offset 5 db from the CCIR mux curve position during addition. The DCA loading approach places nearly equal emphasis upon the mux and radio BINR. The CCIR loading gives prime emphasis to the mux BINR. The mux curve shape is identical in both cases. The assumed multiplex BINR of -69 dbmØ is overlayed on the DCA SNNPR radio curves at 59 db NPR. The same -69 dbmØ is placed on the CCIR radio curve at 54 db NPR. Thus, there must be two link 'standard' curves, one for DCA design baseband loading, and one for CCIR designs.

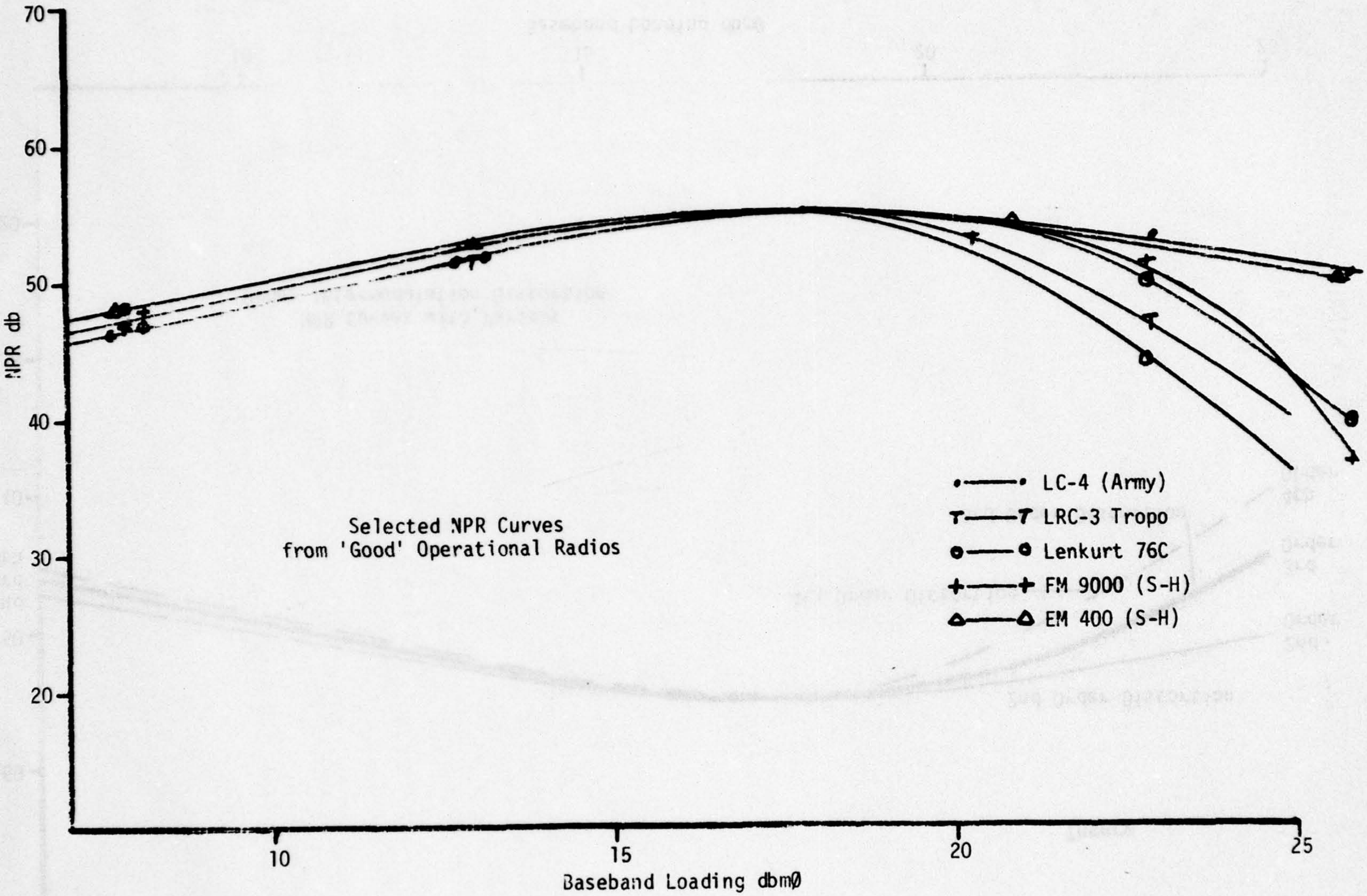
The final proof test of any performance assessment approach is the accuracy with which operational data correlates. Figure VI -10 is the CCIR SNNPR link curve derived from theoritical information. The two sets of CCIR operational TEP link data previously plotted in Fig. V-5 and 11 are entered. As can be seen, with one exception, the Philco LC-4 data correlated well. The one exception is off less than 1 db. The Siemens-Halske data partially checks, but the actual idle channel measured performance is 0 to 1½ db better than the measured NPR would indicate.

This is not difficult to explain. The following table shows the radio and mux BINR and the resultant link noise floor.

	Radio BINR	Mux BINR	Link BINR Noise Floor
Theory Assumed	61 db	-69 dbmØ	-68.2 dbmØ
LC-4/8 Measured	61 db	-70 dbmØ	-69.0 dbmØ
Siemens-Halske Measured	64 db	-71 dbmØ	-70.4 dbmØ

It would be expected that the LC-4/8 data would check since the measured BINR figures agree to less than 1 db with the assumed numbers in the theoretical SNNPR curve representation. The Siemens-Halske measured performance was 3 db better in the radio and 2 db improved in the mux. The resultant link noise floor is 2.2 db quieter. Thus the 1 to 2 db offset in the Siemens-Halske measured performance validates the theoretical curve construction, but leaves a 1 to 2 db resultant operational extrapolation error.

Thus a problem is posed. There is an operationally acceptable rational. It is true that some older radios probably would require considerable work to achieve BINR values much better than 61 db. The operational gain is a fraction of a db-clearly not worth the effort. The multiplex BINR is more important, and accounts for the bulk of the link noise floor at light baseband loading. The quieting of a mux results in almost a db for db gain. If the mux BINR were -60 dbmØ it would obviously be operationally useful to quiet it. If the mux BINR were -69 dbmØ, it would not be worth the effort to achieve the remaining db or two achievable. Therefore we are left with the original dilemma. The theoretical curve cannot accurately represent all DCS data. The solution has already been portrayed in the theoretical curves. Radio BINR of 61 db is reasonable and achievable. Mux BINR of -69 dbmØ is reasonable and achievable. Link noise floors quieter than -68.2 dbmØ (-69.7 dbmCØ) achieve little operational gain. Therefore, standardization is made on the 61 db and the -69 dbmØ numbers and the resultant SNNPR link curves. Most links will perform 'like new' quite closely to the theoretical curves. Those few links where the hardware is quieter than the theoretical standard are permitted 1 to 2 db degradation in NPR or 1 to 2 db increase in BINR without any management recognition of the deterioration. This is not a matter of operational concern since the 1 or 2 db degraded performance is still 'like new' on most links and no operational degradation is observable.



70
60
50
40
30
20
NPR db
10
15
20
25
Baseband Loading dbmØ
Selected NPR Curves
from 'Good' Operational Radios
LC-4 (Army)
LRC-3 Tropo
Lenkurt 76C
FM 9000 (S-H)
EM 400 (S-H)

Fig. VI - 1

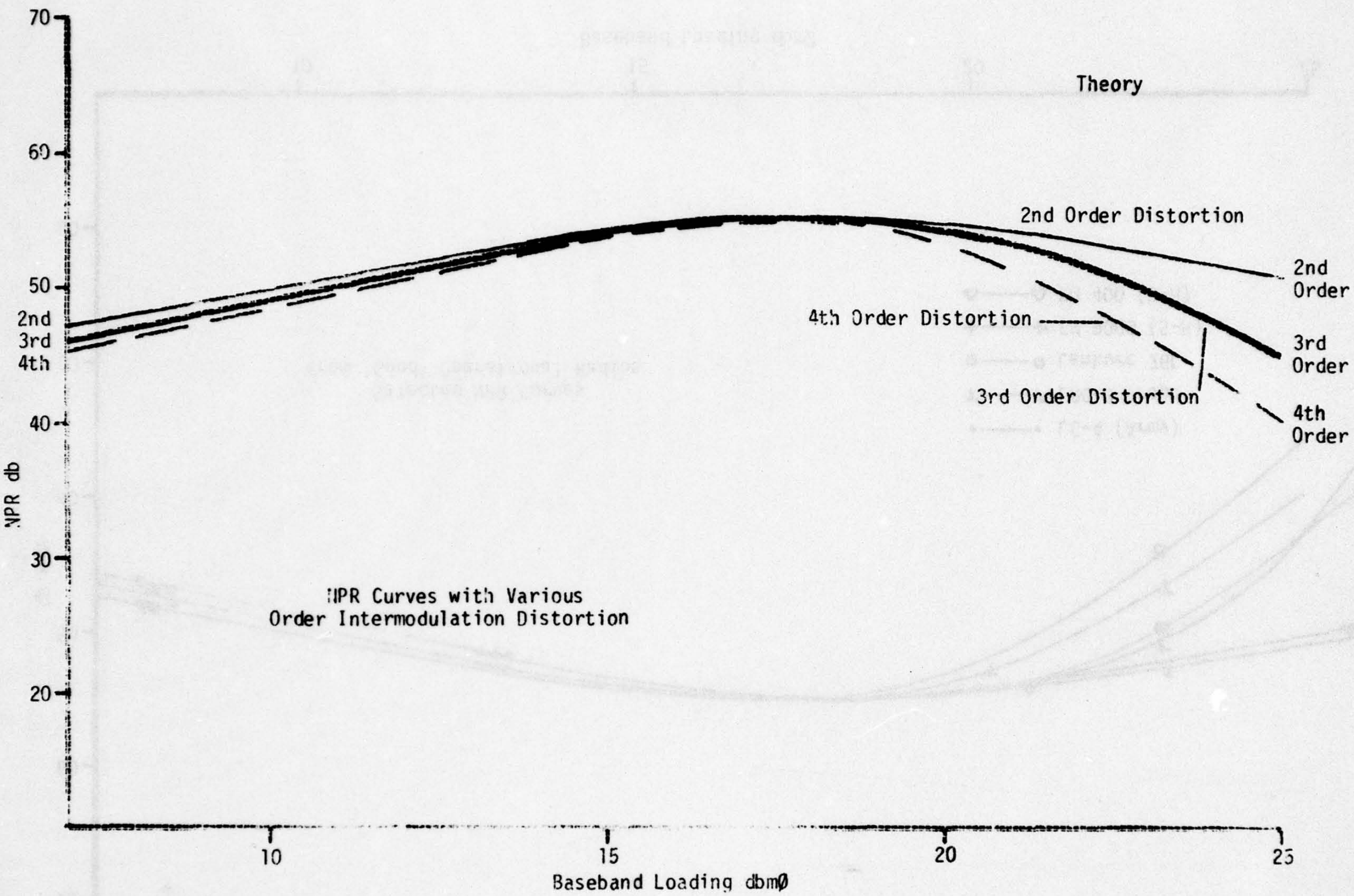

Theory
2nd Order Distortion
2nd Order
3rd Order
4th Order
4th Order Distortion
3rd Order Distortion
NPR Curves with Various Order Intermodulation Distortion
NPR db
70
60
50
2nd
3rd
4th
40
30
20
10
15
20
25
Baseband Loading dbmØ

Fig. VI - 2

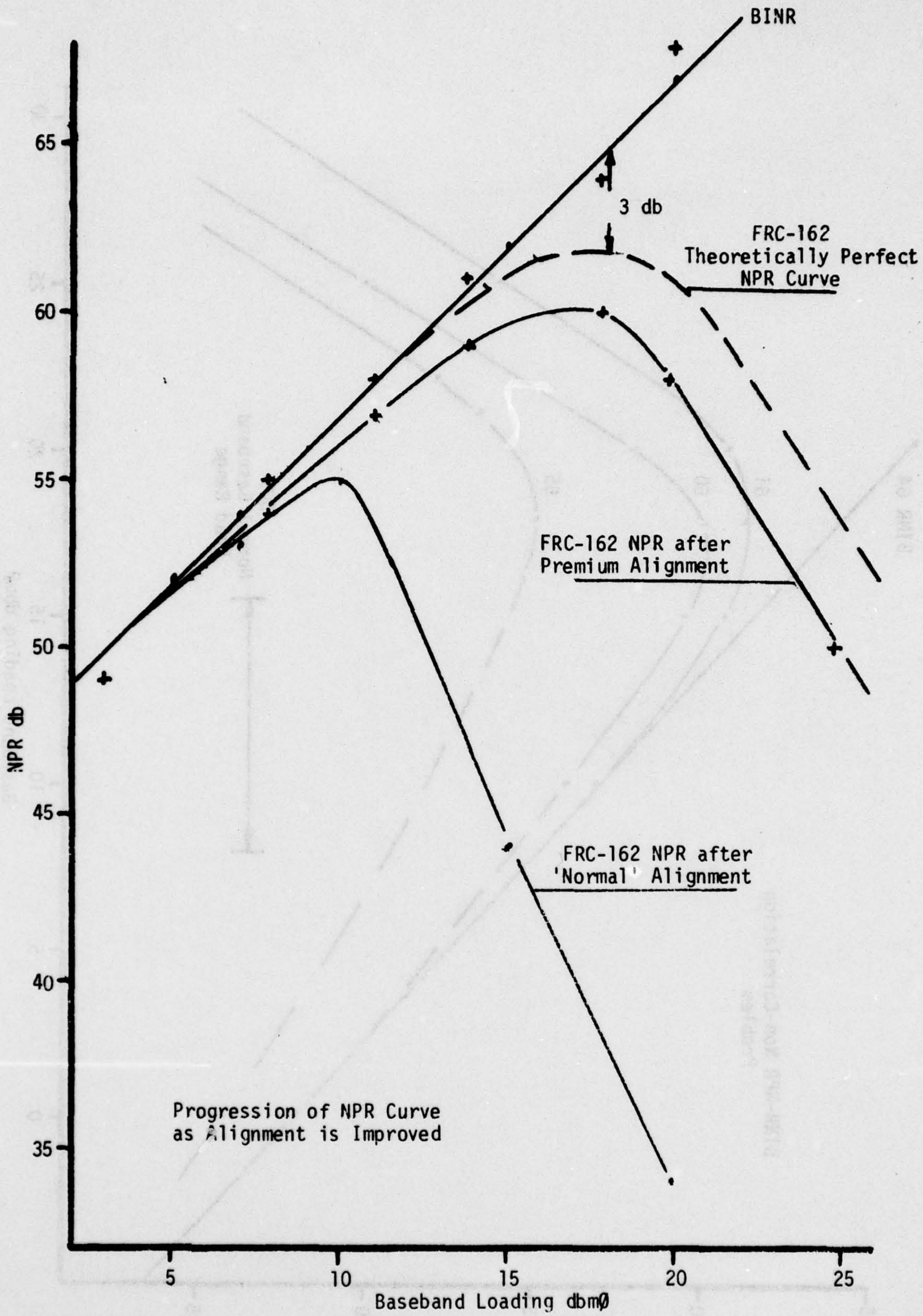

BINR
3 db
FRC-162
Theoretically Perfect
NPR Curve
FRC-162 NPR after
Premium Alignment
FRC-162 NPR after
'Normal' Alignment
Progression of NPR Curve
as Alignment is Improved
65
60
55
50
45
40
35
NPR db
5
10
15
20
25
Baseband Loading dbm0

Fig. VI - 3

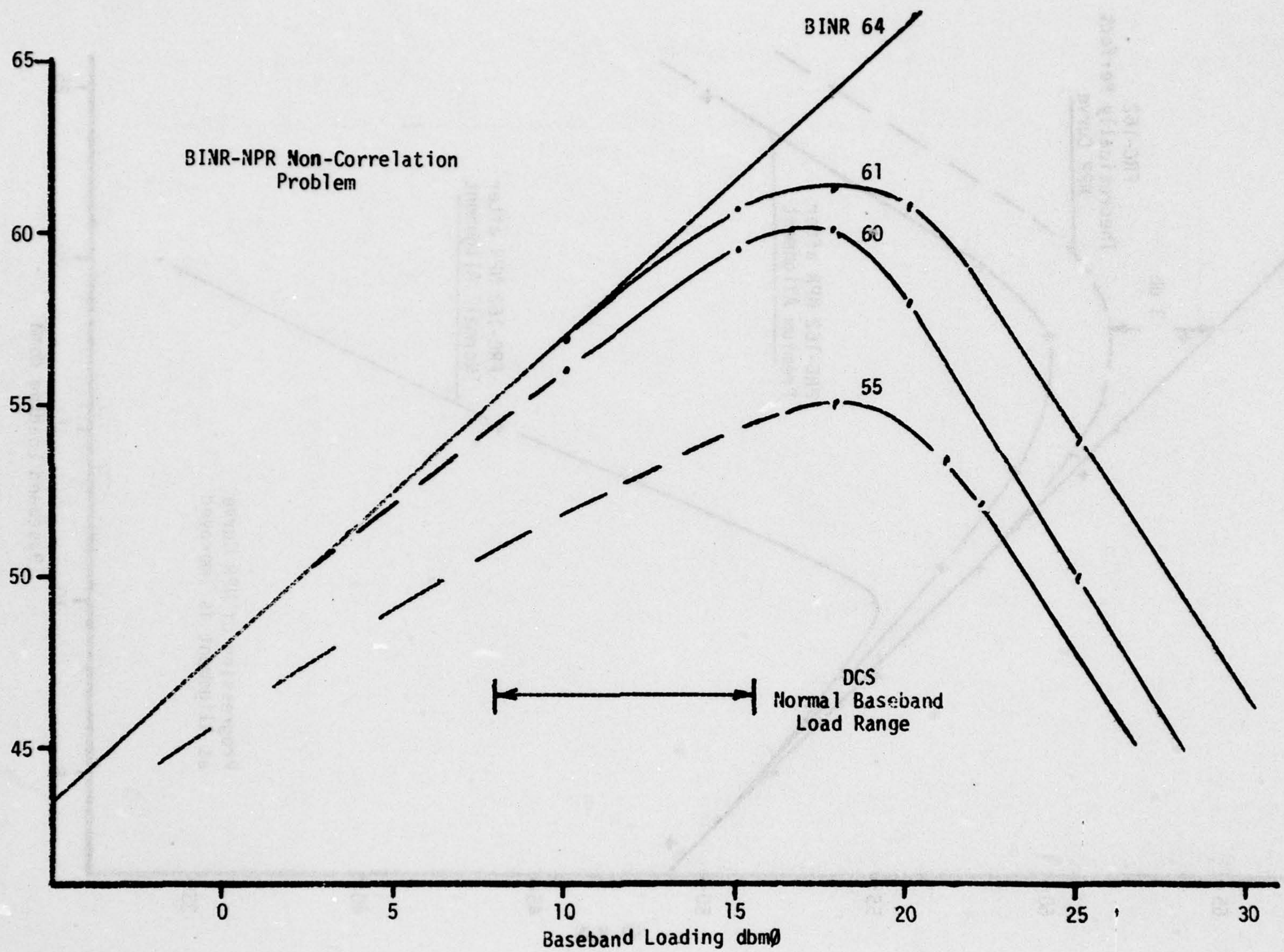

BINR 64
BINR-NPR Non-Correlation Problem
61
60
55
DCS
Normal Baseband
Load Range
65
60
55
50
45
0
5
10
15
20
25
30
Baseband Loading dbmØ

Fig. VI - 4

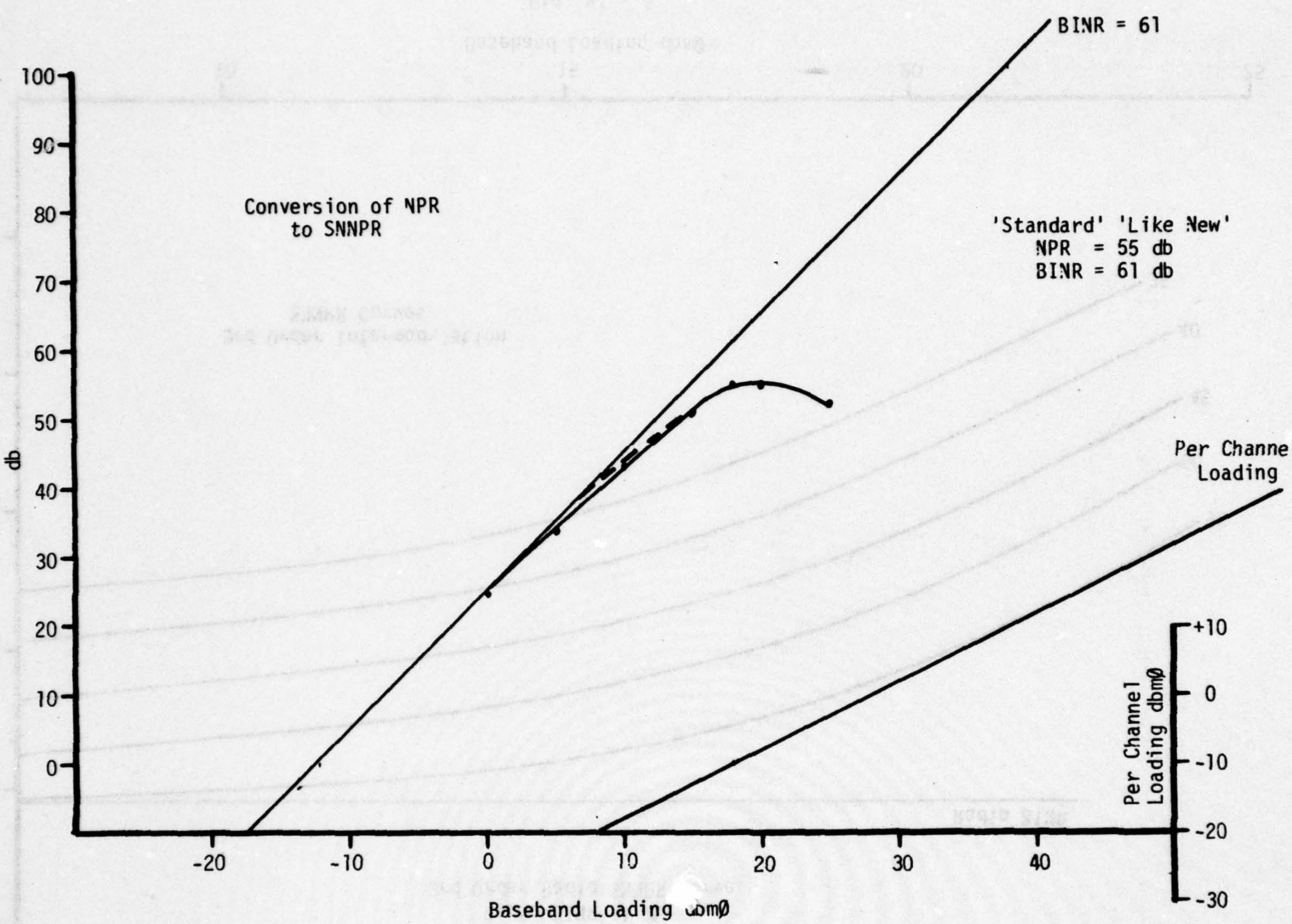

BINR = 61
100
90
80
70
60
50
40
30
20
10
0
db
Conversion of NPR
to SNNPR
'Standard' 'Like New'
NPR = 55 db
BINR = 61 db
Per Channel
Loading
+10
0
-10
-20
-30
Per Channel
Loading dbm0
-20
-10
0
10
20
30
40
Baseband Loading dbm0

Fig. VI - 5

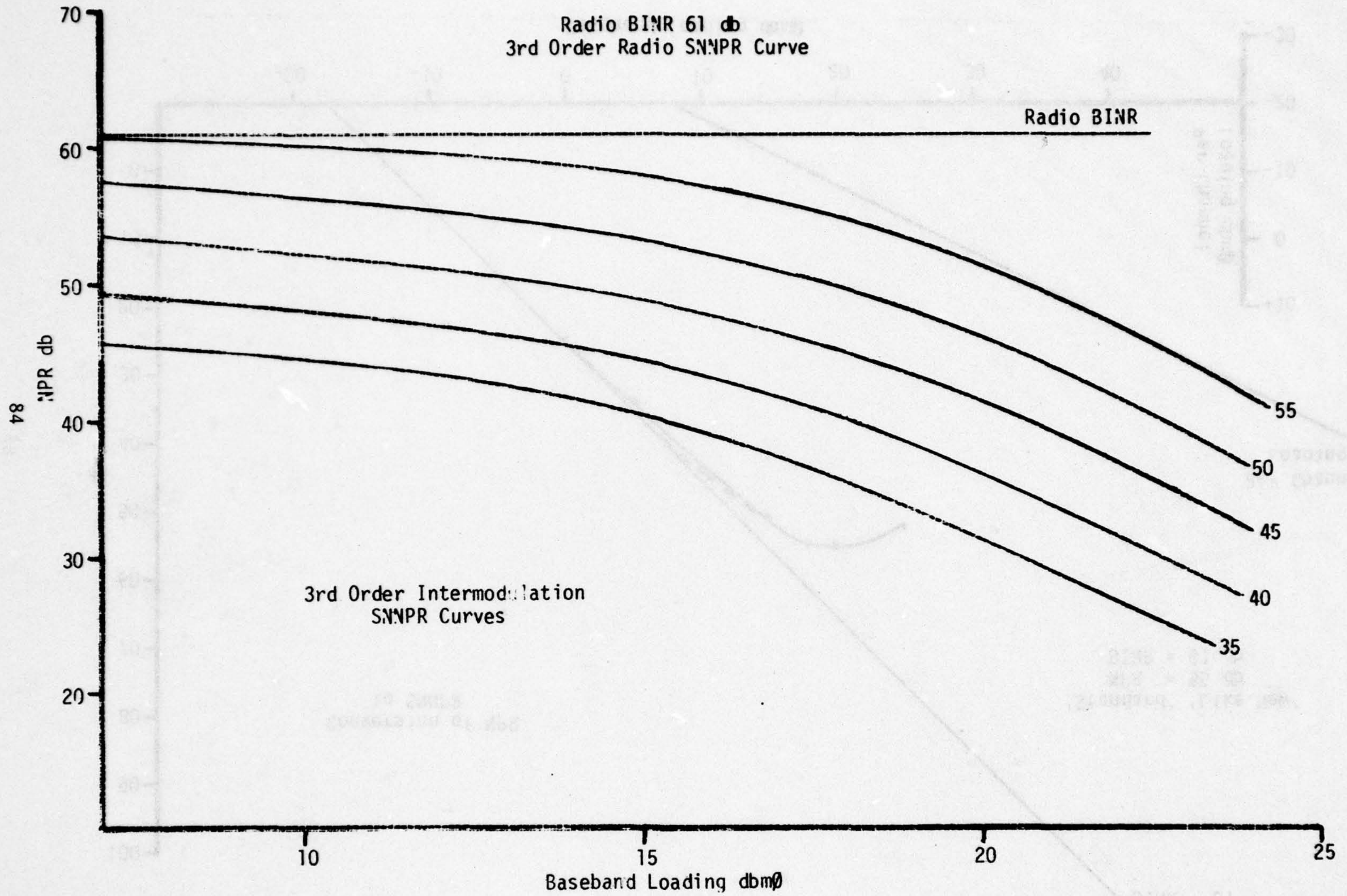
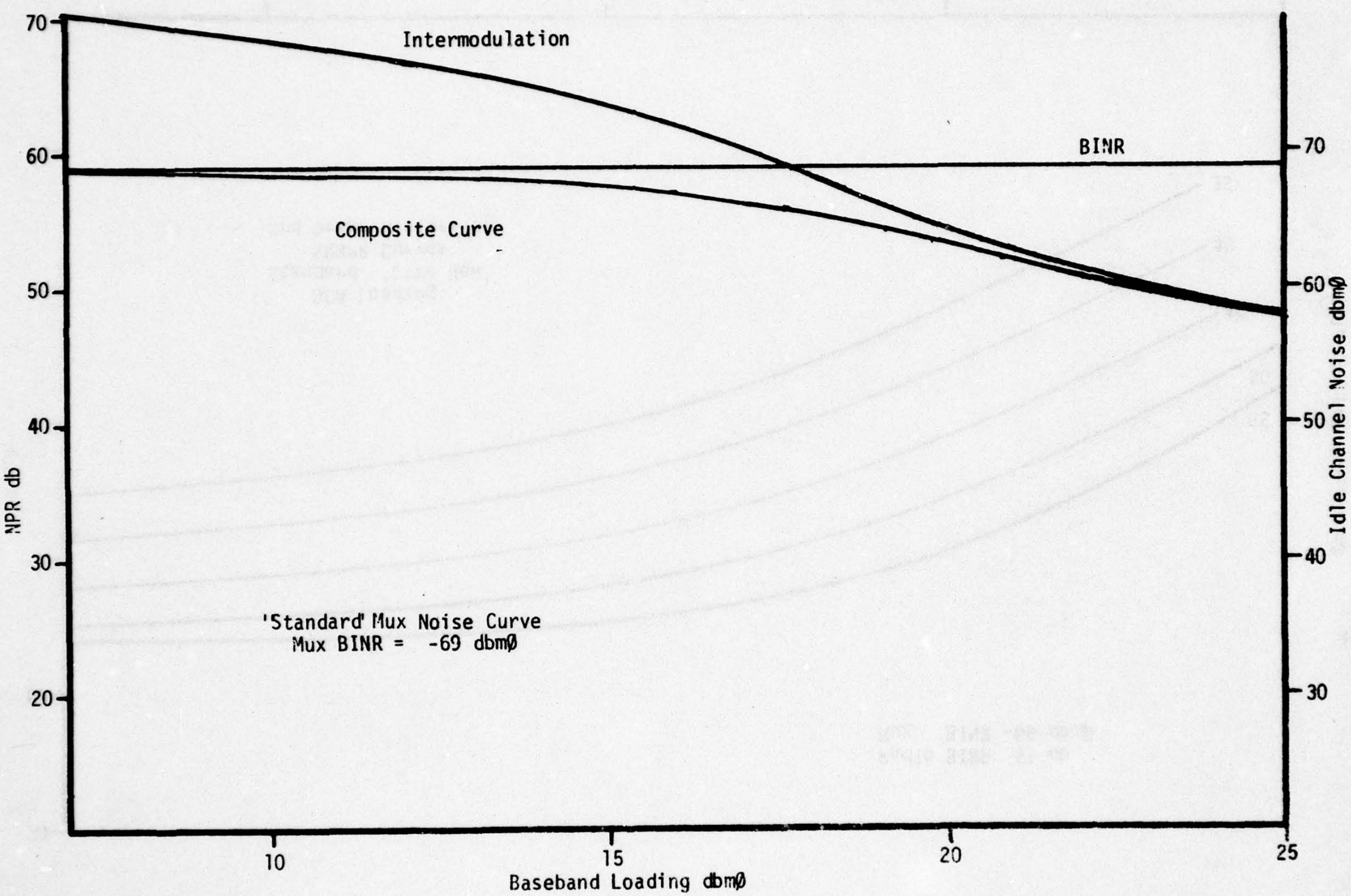

Radio BINR 61 db
3rd Order Radio SNNPR Curve
Radio BINR
3rd Order Intermodulation
SNNPR Curves
NPR db
70
60
50
40
30
20
10
15
20
25
55
50
45
40
35
Baseband Loading dbm0

Fig. VI - 6



Intermodulation
BINR
Composite Curve
'Standard' Mux Noise Curve
Mux BINR = -69 dbmØ
NPR db
70
60
50
40
30
20
Idle Channel Noise dbmØ
70
60
50
40
30
10
15
20
25
Baseband Loading dbmØ

Fig. VI - 7

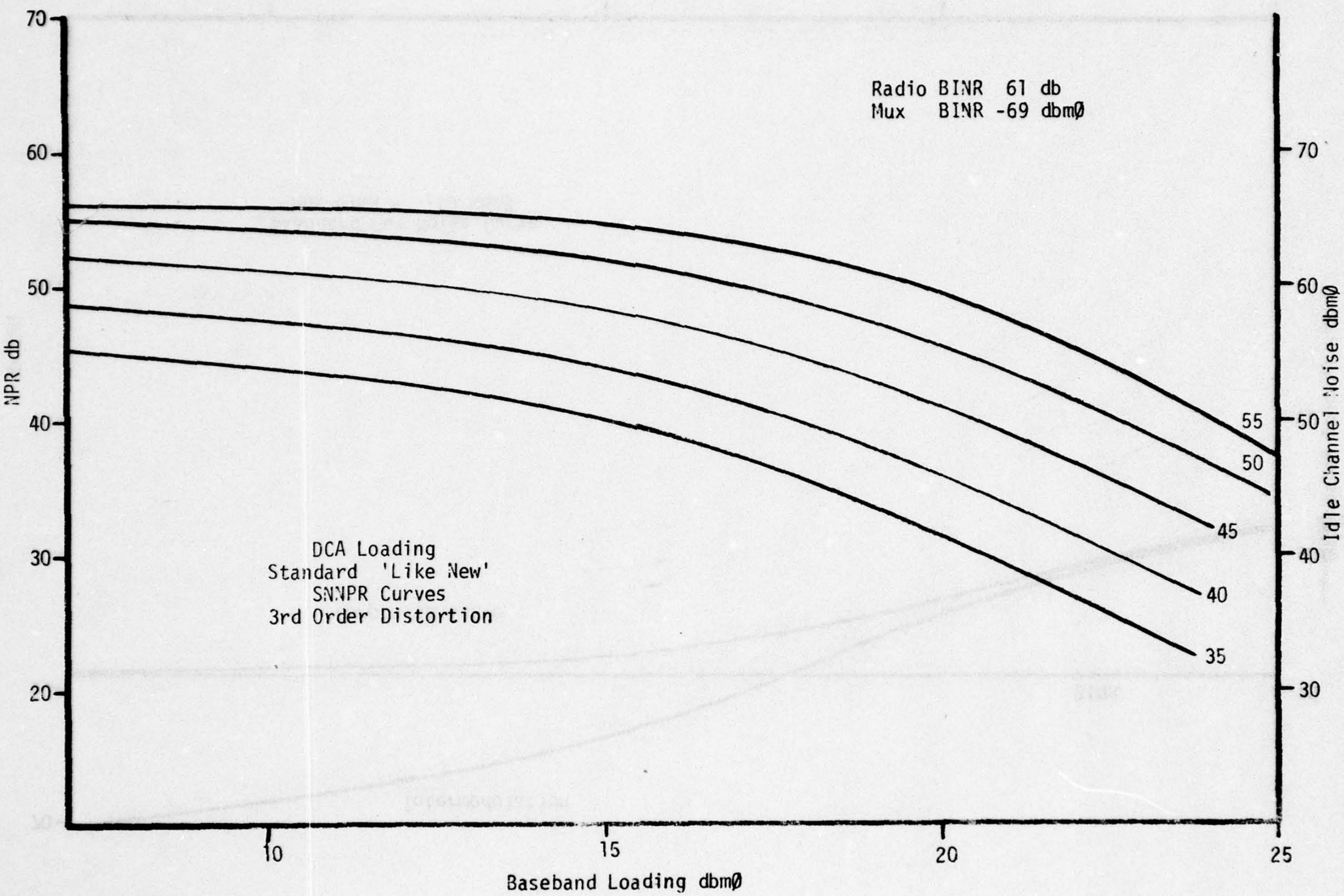

70
60
50
40
30
20
NPR db
Radio BINR 61 db
Mux BINR -69 dbmØ
DCA Loading
Standard 'Like New'
SNNPR Curves
3rd Order Distortion
55
50
45
40
35
70
60
50
40
30
Idle Channel Noise dbmØ
10
15
20
25
Baseband Loading dbmØ

Fig. VI - 8

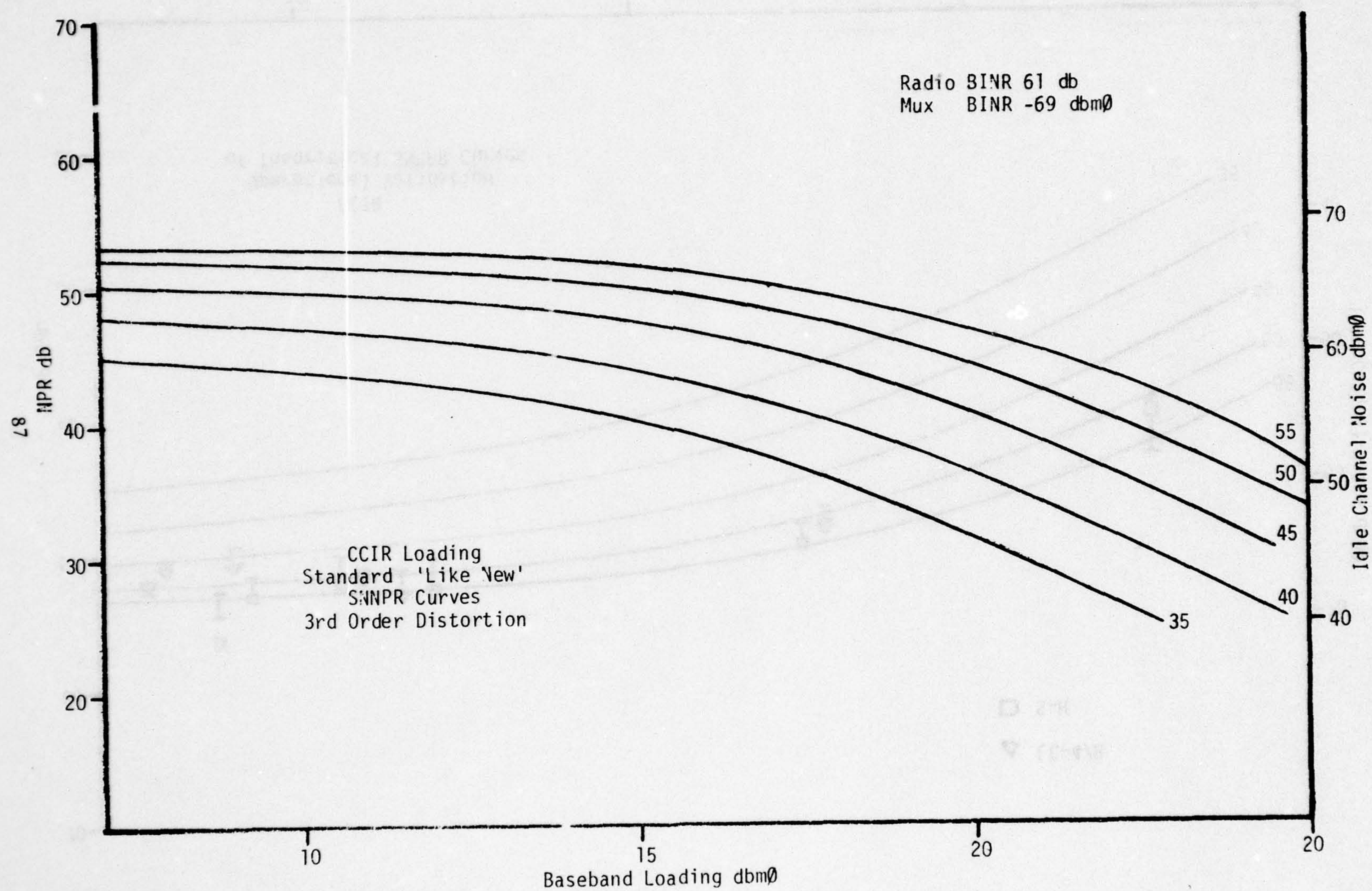
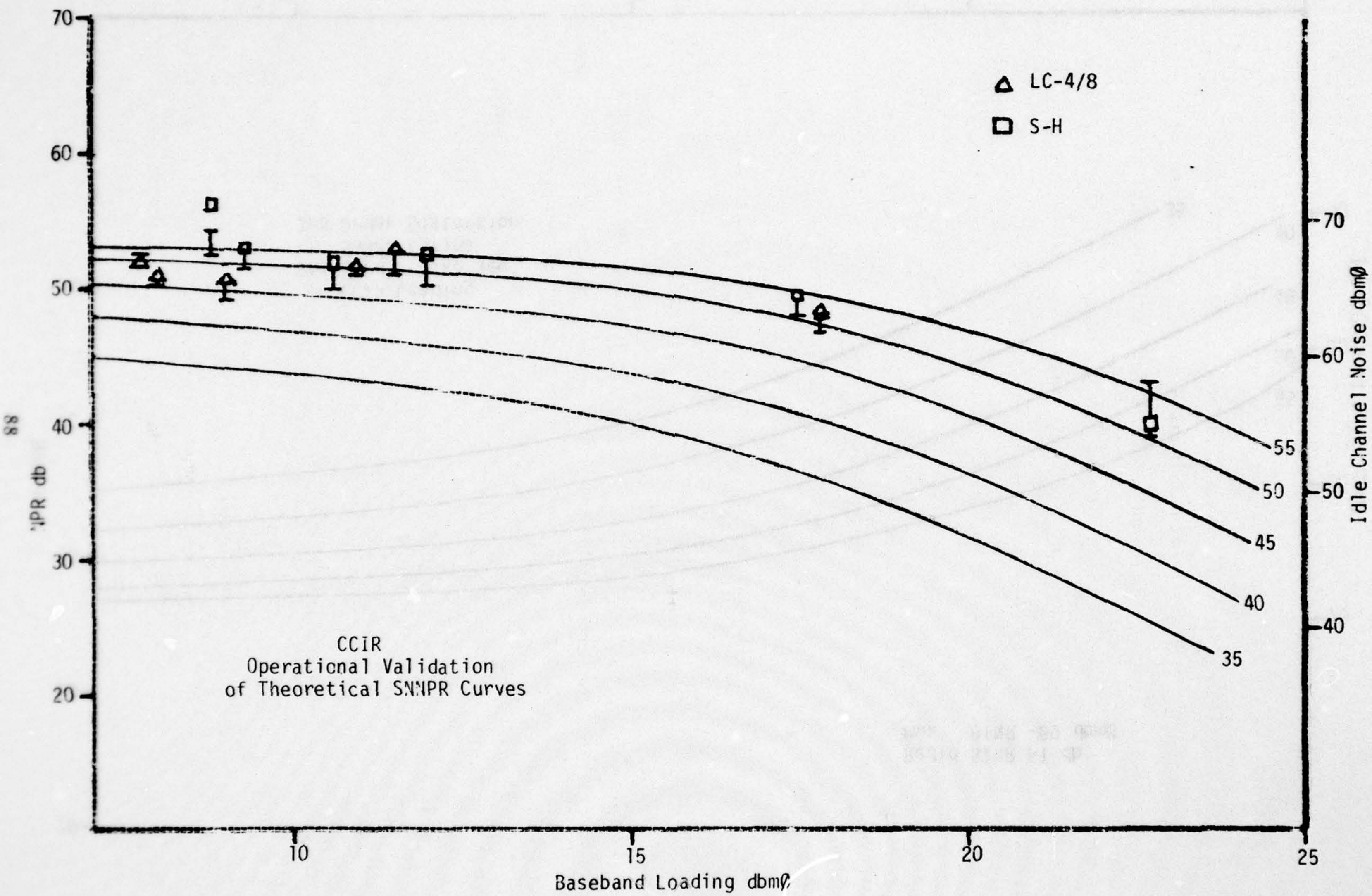

Radio BINR 61 db
Mux BINR -69 dbmØ
CCIR Loading
Standard 'Like New'
SNNPR Curves
3rd Order Distortion
NPR db
Idle Channel Noise dbmØ
Baseband Loading dbmØ
70
60
50
40
30
20
10
15
20
55
50
45
40
35

Fig. VI - 9



70
60
50
40
30
20
NPR db
10
15
20
25
Baseband Loading dbm0
70
60
50
40
Idle Channel Noise dbm0
55
50
45
40
35
LC-4/8
S-H
CCIR
Operational Validation
of Theoretical SNNPR Curves

Fig. VI - 10

AD-A056 587 STATE UNIV OF NEW YORK AT BUFFALO AMHERST DEPT OF ELE--ETC F/G 17/2.1
TEST VALIDATION OF EQUIVALENT FULL LOAD IDLE CHANNEL NOISE CONC--ETC(U)
JUN 78 R L FEIK F30602-75-C-0122
UNCLASSIFIED RR-3-78 RADC-TR-78-125 NL

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VII Conclusions

1. The basic conclusion is clearly that the SNNPR and Equivalent Full Load Idle Channel Noise estimation concept is both theoretically sound and operationally practical.

2. The operational application of the SNNPR concept is simple whether the distortions are amplitude or phase related. There are no errors introduced from either class of degradation alone or in combination, assuming only that the sampled audio channels are distributed somewhat across the whole baseband.

3. The operational accuracy in the special test was generally less than ± 2 db for estimating the radio NPR, and for extrapolation to the full load ICN. The accuracy in the TEP report examination was even better where the radio NPR and mux BINR are specifically extracted and combined. The only exception is where the BINR is excessive. In these cases, normally a noisy multiplex, the NPR degradation is over estimated.

4. The theoretical SNNPR curve, universally applicable to all normal microwave links, give accuracy within ± 2 db for most cases and +3, -2 db on all examined specific TEP reported links.

5. The SNNPR concept is much more accurate than the DCA PMP reporting program, and gives results usable and reliable for precise management addressment. This new approach clearly highlights the degraded links even when the baseband loading is very light. It also avoids the problem of making PMP measurements at specific hours when tech control loads may be very high.

6. SNNPR and extrapolated ICN approach does not produce absolutely precise results when the BINR if excessive, but the SNNPR always detects the degradations, and the errors are reasonable. The PMP program in contrast fails to detect deteriorations if the baseband loading is light - and

underloading is normal. The, the PMP program reports always underestimate the true degradation status of the link, and subsequent failures, and network problems are a surprise to the DCS.

7. The PMP program was a major step forward for the DCS in 1970, when first evaluated. The SNNPR concept is as precise as is warranted for the FDM-FM DCS and certainly is the proper and suitable approach for 1978.

8. The above study and TEP test data described the observations that are specifically true for the Collins FRC-162 test, the Siemens and Philco radios, and as proved by the theoretical study, true for all FM radios.

9. There have been numerous questions raised as to whether the PMP program, diminishes or eliminates the need for the TEP program. Clearly PMP has found some troublesome links without the TEP. The SNNPR will come very near to removal of the routine TEP assessment of most links, although use of the TEP approach to resolve and correct difficulties will still be required,

VIII Recommendations

A SNNPR vs PMP

1. Since the field test and the TEP report analysis substantiate the basic accuracy and relevance of the SNNPR concept, it would seem appropriate to conduct a geographically limited field trial. The necessary SNNPR data could be generated from the specific NPR curve or using the theoretical 3rd order distortion NPR curve. The SNNPR curve can be subsequently validated as a part of the routine TEP effort.

2. Obviously, a region likely to remain relatively undisturbed by major overbuilds would be desirable. Clearly, some links that are marginal or troublesome while still staying PMP Green should be included. The extent of the test region should be large enough to include 25 + links.

3. The concept should be examined by the field personnel who would use the data to guide the maintenance activities, and by local managers to identify problems needing O&M attention. The results must also be investigated by higher level O&M and DCA managers to assess how well the SNNPR concept surfaces problems that have escaped detection by the PMP program. For a period of perhaps three months, these 25+ links should report in both PMP and SNNPR terms. At the end of the test period, a review of the results on an absolute basis, and also as contrasted with the PMP can decide the future course of the SNNPR concept.

B TEP Usage

1. In parallel with the above effort, the SNNPR concept should be inserted into the TEP program for assessment of the link upon arrival at the site and prior to any repair or alignment. It should also be used as described in the 'Technical Evaluation Program Evaluation and Restructuring' Report prepared for DCA by the author to validate and correlate the TEP report data.

2. It is self evident that the measured SNNPR data on all radio types would be useful if only to validate and refine the derived curve. TEP teams in future tests should conduct a standard NPR test, and additionally should perform a SNNPR test at several amplitude degradations, such as 55(or 3 db below BINR) 45 and 35 db. The full set of degraded curves would not be required, but the curves should be conducted at all frequency slots, and at all baseband loading points enabled by the test equipment. This test should be performed only after peak alignment of the hardware.

3. One SNNPR curve should be conducted at 55 db NPR/SNNPR radio conditions over the radio path. Thus, all those malalignments in the radio waveguide, antenna or path are integrated and portrayed. Since no distortions should be present in the 'like new' test, any spread of the frequency slot curves would show phase distortions in the link, and immediately identify problems otherwise noted only by rather sophisticated analysis of the noise across the baseband. This is not possible through the mux until the phase distortions are quite large.

4. Similarly, a SNNPR curve for each class of multiplex should be conducted to refine the theoretical curve. These mux curves need not be reconducted again either in the laboratory or in the field. Once the curve for each type mux has been recorded, only the proper composite top quality mux intermod and BINR would be used to construct the link SNNPR operational curves. The BINR of the mux only should be checked during the link outage, since this identifies needed hardware repair, and locates high station or cabling noise.

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